PEACE/WILLISTON
FISH & WILDLIFE
COMPENSATION
PROGRAM

BC hydro

BRITISH
COLUMBIA

1998 Arctic Grayling (Thymallus Arcticus) Surveys in the Table Anzac And Parsnip Rivers

B. G. Blackman and M. J. Hunter
March 2001

PWFWCP Report No. 237

The Peace/Williston Fish & Wildlife Compensation Program is a cooperative venture of BC Hydro and the provincial fish and wildlife management agencies, supported by funding from BC Hydro. The Program was established to enhance and protect fish and wildlife resources affected by the construction of the W.A.C. Bennett and Peace Canyon dams on the Peace River, and the subsequent creation of the Williston and Dinosaur Reservoirs.

Peace/Williston Fish and Wildlife Compensation Program, 1011 Fourth Ave. 3rd Floor, Prince George B.C. V2L 3H9

Website: *www.bchydro.bc.ca/environment/initiatives/pwcp/*

This report has been approved by the Peace/Williston Fish and Wildlife Compensation Program Fish Technical Committee.

Citation: B. G. Blackman and M. J. Hunter. March 2001. 1998 Arctic grayling (Thymallus arcticus) Surveys in the Table Anzac and Parsnip Rivers. Peace/Williston Fish and Wildlife Compensation Program, Report No. 237. 39pp plus appendices.

Author(s): Brian G. Blackman[1] and Mark J. Hunter[2]
Address(es): [1] Peace/Williston Fish and Wildlife Compensation Program, 1011 Fourth Ave., 3rd Floor
Prince George, B.C. V2L 3H9
[2] BC Conservation Foundation
202-1940-3rd Avenue
Prince George, B.C. V2M 1G7

1998 ARCTIC GRAYLING *(Thymallus arcticus)*

SURVEYS IN THE TABLE, ANZAC

AND PARSNIP RIVERS

Brian G. Blackman[1] and Mark J. Hunter[2]

[1] Peace/Williston Fish and Wildlife Compensation Program, 1011 Fourth Ave.
Prince George, B.C. V2L 3H9

[2]British Columbia Conservation Foundation, #202-1940 Third Ave.
Prince George, B.C. V2M 1G7

March 2001

Citation: B.G. Blackman and Hunter, M.J. 2001. 1998 Arctic grayling Surveys in the Table Anzac and Parsnip Rivers. Peace/Williston Fish and Wildlife Compensation Program, Report No. 237. 39pp plus appendices.

This report has been approved by the Peace/Williston Fish and Wildlife Compensation Program Fish Technical Committee.

105-02251/

ABSTRACT

Arctic grayling (Thymallus arcticus) life history and habitat utilisation was examined on the Parsnip Table and Anzac Rivers, as part of ongoing investigations in these watersheds. The unusually early spring, and low stream flows in 1998, resulted in the fry emerging in early June, one month earlier than in 1997. Fry were also distributed further upstream than in previous surveys and young of the year fry were larger in September than in previous years. Visual surveys were found to be a cost effective method to determine the distribution and relative abundance of newly hatched Arctic grayling fry. However, the timing of the surveys, weather conditions and the ability to identify newly hatched Arctic grayling was critical. This method should be useful to locate spawning areas if the fry remain near the sites where they emerge. September electrofishing surveys of index sites in the Table River found Arctic grayling fry numbed from 30 to 80 per kilometre of stream sampled. Twenty five one year old grayling per kilometre sampled were beach seined from an eight km section of the Parsnip River. This age class showed a strong preference for shallow (60-100cm), low velocity (<0.5 ms^{-1}) glides. This age class did not appear to rear in any significant numbers in the clear tributary streams but favoured the larger and more turbid Parsnip River. Adult grayling counts ranged from 30 to 90 per kilometre from Table and Anzac rivers in the mid and upper reaches, but were less than 4 per kilometre in the lower reaches. Mark recapture methodologies over estimated grayling abundance because marked (floy tagged) fish tended to move out of the index sites. A comparison of scale and fin ray ages found no difference up to age five (~33cm) but scale ages were lower with older fish.

TABLE OF CONTENTS

	Page No.
ABSTRACT	i
TABLE OF CONTENTS	ii
LIST OF APPENDICES	ii
LIST OF TABLES	ii
LIST OF FIGURES	iii
INTRODUCTION	1
STUDY AREA	2
METHODS	5
Temperature Records	5
Egg Deposition Survey	5
Young-Of-The-Year Fry Distribution	5
Young-Of-The-Year Fall Rearing Densities	6
Age 0+(young of the year) and 1+ Arctic grayling Habitat Utilisation	6
Adult Abundance Estimates	7
Comparison Of Ageing Structures	10
RESULTS	10
Temperature Records	10
Egg Deposition Survey	11
Fry Distribution Survey	12
Young of the year fry distribution	13
Young-Of-The-Year Fall Rearing Densities	14
Age 0+ and 1+ Arctic grayling Habitat Utilisation	15
Adult Abundance Estimates	22
Comparison Of Ageing Structures	23
Age Class Distribution of Arctic grayling	23
Pit Tag Retention and Juvenile Growth	23
DISCUSSION	26
Temperature Records	26
Egg Deposition Survey	26
Young-Of-The-Year Fry Distribution	27
Young-Of-The-Year Fall Rearing Densities	28
Age 0+ and 1+ Habitat Utilisation	29
Adult Abundance Estimates	30
Comparison of Ageing Structures	33
Age Class Distribution of Arctic	33
Pit Tag retention and Juvenile Growth Rates	33
Management and Research Needs	33

ACKNOWLEDGEMENTS 35
REFERENCES 35

LIST OF APPENDICES

APPENDIX I Young-Of-The-Year Fry Distribution Data

APPENDIX II Adult Abundance Estimates

APPENDIX III Age 0+ And 1+ Habitat Utilisation Data

APPENDIX IV Arctic grayling fry identification

LIST OF TABLES

Tables		Page No.
1	Mean biweekly water temperatures for 1997 and 1998 from the Parsnip, Table and Anzac Rivers.	11
2	Fish species captured during the fall electrofishing sampling program	15
3	Arctic grayling and total fish densities for the Table River at the bridge crossing (km 22) and the middle ford crossing (km 9.8).	15
4	The number of fish observed per kilometre of stream	22
5	Observations and movements of tagged fish during underwater counts on the Table and Anzac Rivers.	24
6	Comparison of Table and Anzac Rive Arctic grayling growth rates from samples collected from 1995 to 1998.	25

LIST OF FIGURES

Figures		Page No.
1	Table and Anzac Rivers .	4
2	Beach seining sites on the Parsnip and Anzac Rivers.	8
3	Table River mean daily temperature data for 1997 and 1998.	12
4	Anzac River mean daily temperature data for 1997 and 1998.	12
5	Total number of fry (arctic grayling and longnose sucker)counted between kilometre markers on the Table River during the fry distribution survey.	13
6	Total number of fry (arctic grayling and longnose sucker))counted between kilometre markers on the Anzac River during the fry distribution survey.	14
7	Habitat preference of age 0+ Arctic grayling in the Parsnip and Anzac Rivers from depth and velocity measurements taken 1 meter from shore.	17
8	Habitat preference of age 0+ Arctic grayling in the Parsnip and Anzac Rivers from depth and velocity measurements taken 5 meters from shore.	18
9	Habitat preference of age 1+ Arctic grayling in the Parsnip River from depth and velocity measurements taken 1 and 5 meters from shore .	19
10	Habitat preference of age 1+ Arctic grayling in the Parsnip River from depth and velocity measurements taken 10 and 15 meters from shore.	20
11	Habitat preference of age 0 and 1+ Arctic grayling fry in the Parsnip and Anzac rivers from substrate measurements.	21
12	Comparison of fin ray age vs scale age from samples collected from the Table and Anzac Rivers in 1997 - 1998.	23
13	Arctic grayling length frequency distribution for the Table and Anzac Rivers.	25

INTRODUCTION

Arctic grayling populations in the upper Peace River drainage have declined severely since the mid-1980's (Northcote 1993, Blackman et al 1990). This area drains into Williston Reservoir, the largest body (1,736 km^2) of freshwater in British Columbia. This storage reservoir with a drainage area of 70,000 km^2, was formed by the construction of the W.A.C. Bennett Dam in 1968. Very little information is available about fish distribution prior to the creation of the reservoir. Studies conducted in 1974 -75 found Arctic grayling were the most numerous sport fish species found in the majority of rivers tributary to the reservoir (Bruce and Starr 1985) and this species was also abundant in the reservoir (Barrett and Halsey 1985). Arctic grayling had almost completely disappeared from the reservoir (Blackman 1992) and from most moderate to small streams by 1988 (Blackman and Langston 1992). There are still viable Arctic grayling populations in some of the larger rivers entering the reservoir but rapid resource development and improved angler access further threatens these stocks, In response to the decline in the Arctic grayling stocks within the watershed the B.C. Conservation Data Centre has designated the species as "red listed" (QS1) or critically imperilled and catch and release regulations have been imposed. The Peace Williston Fish and Wildlife Compensation Program (PWFWCP) has been conducting projects in this watershed since 1988 with the objective of compensating for impacts caused by the formation of the Reservoir and the flooding of the large riverine habitats.

Arctic grayling are one priority species for this program. To date, projects have documented the decline of Arctic grayling stocks from the reservoir (Blackman 1992), declines in angler catch (Blackman and Newsholme, 1993), and the disappearance of stocks from many small streams entering the reservoir (Langston and Blackman 1992). The Program has provided information to the B.C. Conservation Data Centre to support the "red listed" designation. A review of management and enhancement options in the watershed has been conducted (Northcote 1993). A transplant of adult Arctic grayling into an open barren headwater lake was conducted in 1992 and 1993 but it appears the fish may have tried to return to the area where they had been captured (Langston 1998). A fence trap was unsuccessful in capturing migrating Arctic grayling spawners (Langston and Zemlak 1997). A long term project (1992-2002) to determine the effects of stream fertilisation on Arctic grayling populations has been initiated (Larkin et al 1999). A number of stream inventory surveys have been conducted to determine the distribution of Arctic grayling in both in the watershed and in adjacent area streams. Beginning in 1994 a number of studies, co-funded by Forest Renewal B.C., have been aimed at documenting distribution, relative abundance, habitat utilisation, migratory patterns of Arctic grayling in the Table and Anzac River watersheds (Zemlak and Langston 1995, Langston 1998, Mathias et al 1998, Blackman 2001). In addition, starting in 1996, work has been underway to evaluate the genetic structure and degree of similarity of Arctic grayling populations within the Williston Reservoir watershed (Stamford 2001). The overall goal of these Arctic grayling projects is the preservation and restoration of Arctic grayling stocks and habitats within the Williston Reservoir Watershed. In order to accomplish this goal a management plan is in development (Blackman 2001 in prep) to help direct efforts to determine what factors are limiting Arctic grayling populations, identify critical habitats and develop methods to monitor changes in Arctic grayling populations.

The objectives of the 1998 field program on the Table and Anzac Rivers were:

1. to determine spawner / egg distribution and to document spawning habitat characteristics.
2. to developing methods that can be used to monitor changes in egg deposition and survival rates.
3. to monitor fry emergence timing, distribution and relative abundance and compare with previous studies.
4. to evaluate the effectiveness of fry distribution studies in determining main spawning areas.
5. to document fall fry rearing densities.
6. to locate the 1+ Arctic grayling (previous studies have been unable to locate one year old (1+) Arctic grayling), and determine what habitats this age class uses.
7. to establish index sites in the Table and Anzac Rivers to monitor long term changes in adult populations as a result of industrial and restoration activities.
8. to access the effectiveness of mark recapture methodologies using underwater counts to estimate Arctic grayling populations.
9. to compare the use of fin rays and scales to age grayling.

In addition to these primary objectives, length, and weight data were collected, tissue samples were collected for genetic analysis (for a related project) and all sport fish collected were marked with a numbered floy tag and / or a PIT (passive integrated transponder) tag and thermographs were used to record water temperatures.

STUDY AREA

Williston Reservoir, formed by the construction of the W.A.C. Bennett Dam in 1968, covers an area of 1,736 km^2, and has a drainage area of 70,000 km^2 (Bruce and Starr 1985). It has three main reaches, the Finlay, Parsnip and Peace entering from the north and south and draining to the east respectively.

Life history and habitat utilisation studies on Arctic grayling have been conducted on the Table and Anzac rivers (100 km north of Prince George, B.C.) since 1994. The two rivers flow west out of the Misinchinka Ranges of the Rocky Mountains to drain into the Parsnip River 75 km upstream from Williston Reservoir. The Parsnip River and its tributaries are the southern most extent of Arctic grayling in B.C. The physical characteristics of these streams are very similar but the Anzac is in a relatively pristine state, where as the Table River has been seriously impacted by resource development.

The Table River (54°42' 122°17') drains a 506 square kilometre watershed (Fig 1) and is 56 km in length with an average gradient of 0.7 %. The upper reaches (3 to7) have a moderate gradient (1-2%) and are frequently confined in their channels. Reaches one and two are low gradient (<0.5%) and are unconfined on the 1 to 2 km wide valley flats. These reaches have tortuous meanders with many old ox bows, side channels, and abandoned channels. Reach one

and the lower section of Reach two flow through an area of fluvial silt deposits and as a result bank stability is poor and there is a high percentage of fines in the substrate. Up to 40% of the stream channel has been logged up to or in the riparian zone (Mathias *et al.* 1998). A rail line, built by B.C. Rail in the late 1970's to service the Tumbler Ridge Coal Development Project, runs along the majority of the length of the river. The railway construction severely impacted fish production in the system because of extremely heavy silt loads and slide activities. This continued for a period of up to five years during the early 1980's (D. King, pers comm, B.C. Environment Habitat Protection Prince George)

The Anzac River (54°48' 122°32') drains a 939 square kilometre watershed (Fig. 1) and is 78 km long with an average gradient of 0.7%. Reach four is a bedrock canyon with a moderate gradient (1-2%). Reaches one and two are low gradient (<0.5%), and unconfined on 1 to 2 km wide valley flats. They are similar to the lower Table River with tortuous meanders, old ox bows, side channels and abandoned channels. Reach two is multi-channelled and has some areas with fluvial silt deposits. The substrate of Reach one is composed of more gravels and cobbles with fewer fines than in the Table River and bank stability is good. The lower valley flats were logged in the 1940's, but have successfully grown back (Mathias *et al.* 1998). Both systems have waterfalls (km 47 Anzac R. and km 37 Table R.), which block Arctic grayling access to the upper watersheds.

A 25 km long section of the Parsnip River between the Table and Anzac Rivers was included as part of the study area in 1998. The Parsnip River flows from just north of Prince George for 175 km to Williston Reservoir and has a drainage area of 4,669 km^2 (Bruce and Starr 1985). This river is low gradient (0.3%) and is unconfined. Much of the soil adjacent the river is composed of fluvial silts and as a result bank stability can be poor and water clarity is low.

The Parsnip River had a mean daily flow rate to 142 m^3/sec from 1985 to 1995. During this period, the average maximum daily flow rate was 824 m^3/sec and the minimum 23 m^3/sec. Spring break-up usually occurs in April with peak flows occurring in late May. The lowest flows occur between September and March, with freeze-up occurring in November (Water Survey of Canada). There is no historic flow data for the Table and Anzac Rivers.

Fish species identified in the Table, Anzac and Parsnip rivers include: Arctic grayling *(Thymallus arcticus)*, bull trout *(Salvelinus confluentus)*, rainbow trout *(Oncorhynchus mykiss)*, mountain whitefish *(Prosopium williamsoni)*, lake whitefish *(Coregonus clupeaformis)*, burbot *(Lota lota)*, northern squawfish *(Ptychochelus oregnensis)*, largescale suckers *(Catostomus macrocheilus)*, longnose suckers *(Catostomus catostomus)*, white suckers *(Catostomus commersoni)*, slimy sculpins *(Cottus cognatus)*, prickly sculpins *(Cottus asper)*, and longnose dace *(Rhinichthys cataractae)* (Anonymous 1978).

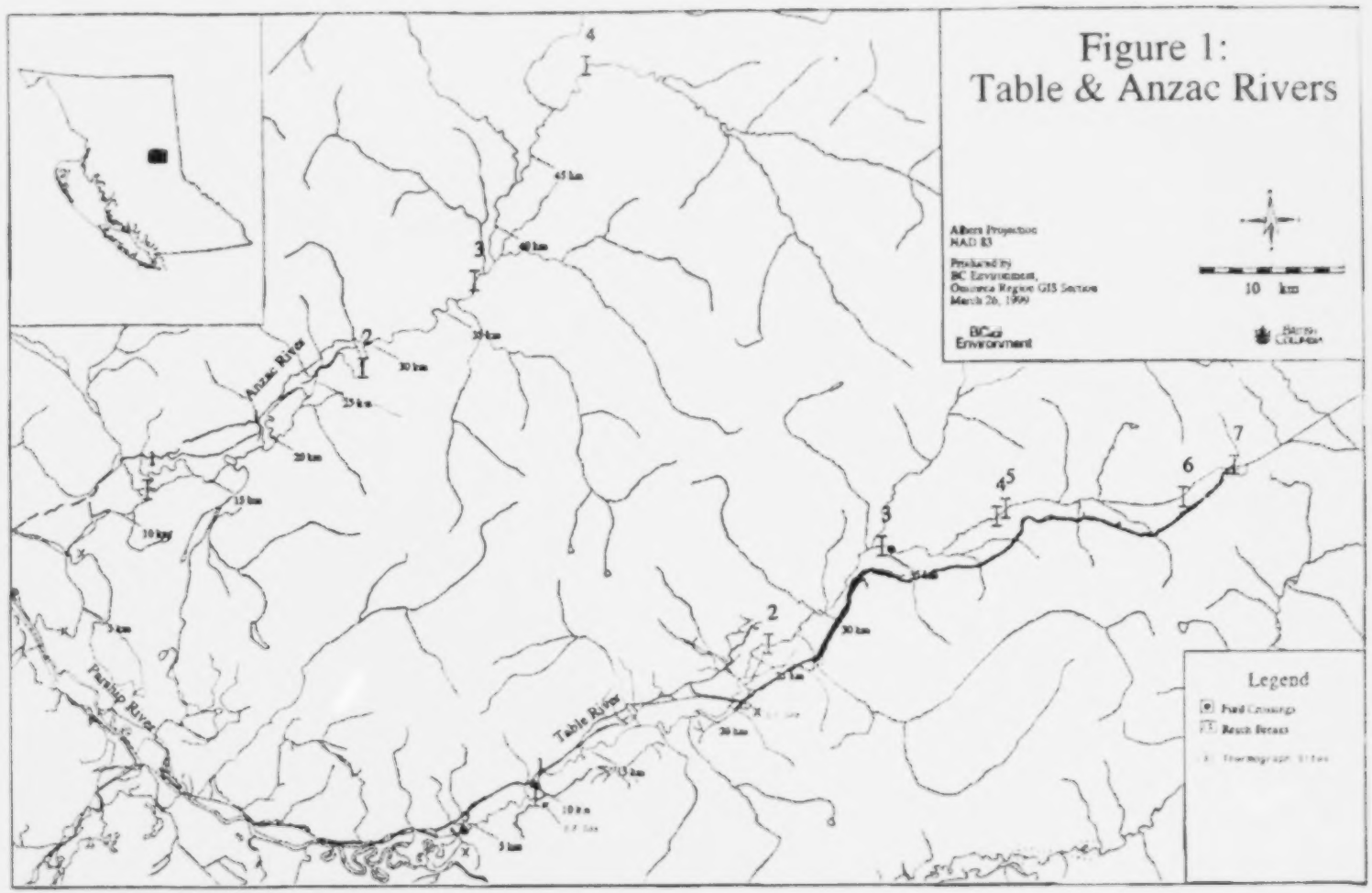
Figure 1:
Table & Anzac Rivers
Albers Projection
NAD 83
Produced by
BC Environment,
Omineca Region GIS Section
March 26, 1999
10 km
BC Environment
Anzac River
Parsnip River
Table River
Legend

METHODS

Temperature Records

Two temperature loggers (Onset Optic temperature loggers) were installed in the Table River, two on the Anzac Rivers and 1 on the Parsnip River (Table 1) to record hourly water temperatures from May 28th to October 29th, 1998

In order to compare temperature data with previous studies the loggers in the Anzac River (km 3) and Table River (km 22) were installed at sites utilised in 1997 (data on file).

Egg Deposition Survey

In order to locate Arctic grayling spawning areas a visual survey was conducted by walking along the bank between km's 5 and 6 of the Anzac River on June 10, 1998. This stretch of river was chosen because previous studies (Blackman 2001) indicated this was an important spawning area

A 300 m length of shoreline habitat, 3 m wide, was surveyed looking for evidence of spawning in the river substrate. Subsequently sixty random sites in this same section were examined for eggs. An oar was used to disturb the gravel in 1 square meter sites and a 0.5mm mesh fyke net was used on the downstream side of the site to collect materials disturbed from the gravels. Arctic grayling bury their eggs in only 2 to 3 cm of gravel (Van Whye 1962, Kratt and Smith 1977) so the eggs would be easy to dislodge from the "redd". The water depth ranged from 0.1 to 0.5 m and the velocities were 0.2 to- 0.75 m/s over gravel substrate at the sites examined which should be suitable spawning habitat.

A similar survey was initiated on the Table River at km 28, but newly hatched fry were discovered and it was assumed that eggs had already hatched so the egg deposition survey was stopped.

Young-Of-The-Year Fry Distribution

Preliminary fry distribution surveys were conducted on the Table and Anzac Rivers from June 16 to 18, 1998. Two crews surveyed 31 index sites (Blackman 2002 in prep), which were 100 to 200 m in length to determine the scope and distribution of Arctic grayling fry emergence. Two crews of observers walked up stream through alternate sites counting the fry. Polarised glasses were worn to improve sightability of the fry. For each section, the NAD 83 UTM co-ordinates of the start location, the number of fry counted per 50-m of stream bank, and the type of habitat where Arctic grayling were observed was recorded. Samples were collected from schools of fry and preserved in ethanol (for genetic analysis) or formaline (for identification), and were subsequently examined by Dr. D. McPhail and M. Stanford at the University of British Columbia (UBC).

This was followed by detailed surveys of the lower 32 km of the Table River which started on June 30th. These surveys were similar to the initial surveys except all walkable areas were visually searched. Special attention was given to key habitats such as gravel bars, shallow shoreline areas, back channels, alcoves formed at the top of the gravel bars, and side channels. These are the types of habitat that have been identified as Arctic grayling fry habitat (Armstrong 1986). Each crew covered a 0.2-1.0 km section with the downstream crew being "shuttled" up to the next section by helicopter. This procedure was repeated on the lower 20-km of the Anzac River from July 7 to 9, 1998.

Young-Of-The-Year Fall Rearing Densities

Two areas of the Table River, (km 9.8 and km 22) with road access and where fry had been located previously (Mathias et al 1998), were chosen as electrofishing sites to establish a rearing density index for the Table River (Fig 1). Sampling sites were located immediately upstream and downstream of these access points. Mainstem shoreline, mainstem and side channel sites were sampled.

A 32 m long, 3 mm mesh net, held in place with rebar and anchored to the bottom with stones, was used to enclose 25 m x 3 m sites along the shoreline. Two nets were used to isolate full sections of river 25 m in length and entire side channels were also netted off and sampled. The rebar was pounded into the riverbed 4 hours prior to setting the nets to allow the fish to settle. A Smith-Root Mark 12B Electroshocker (set at J8 8 - 0.4 ms at 60 Hz and 500 volts) was used to capture fish. A minimum of 2 passes were completed for all sites. If any Arctic grayling were caught on the second pass a third pass was completed. All Arctic grayling, rainbow trout and bull trout were sampled for length and weight. All other fish species had a minimum and maximum length, weight and the total number of fish recorded. Abundance estimates were calculated using Microfish 3.0 software (removal method available from American Fisheries Society).

Age 0+(young of the year) and 1+ Arctic grayling Habitat Utilisation

Three sampling sessions were conducted on the Parsnip and lower Anzac Rivers, two between July 14 and 24, and the third from September 8 to 10, 1998. A variety of suitable (for beach seining) habitats were sampled over an 8 km length of river.

A 30 x 4.0 m beach seine (with 9 mm mesh) was used to capture fish. Fork length (mm), weight (g) and a scale and/or fin ray sample was collected from all Arctic grayling, rainbow trout and bull trout. PIT (passive integrated transponder) tags were applied to all Arctic grayling over 100 mm, using the methods outlined by Prentice et al (1990 and 1990a). Adipose fins were collected from all Arctic grayling for genetic analysis as part of a program to determine stock variability in the watershed. All other species captured in the beach seine were sampled for a minimum and maximum length and total number. Capture locations were recorded by UTM co-ordinates and site or net set number.

After the initial session (July 14-17) was completed, it was decided to carry out additional netting (July 21-24, 1998) to insert more PIT tags and gather information on habitat (site) preference of age 1+ Arctic grayling. Each seine set was specifically identified (Site 1A, 1B, 1C...) and the number of each fish species captured for each set was recorded. Each site (net set) length (shoreline) was recorded in meters and water velocities (m/s), depths (m) and substrate composition (%) was recorded in 25 m transects along the site at 1 m, 5 m, 10 m and 15 m distances from shore. Water velocities were measured at 60% of the water column depth using a Swoffer Instruments Inc. Model 2100 Series current meter. Substrate was evaluated visually and recorded as percentages of fines, gravels, cobbles and boulder. Values collected were averaged for each distance from shore based on the transects. For example in a 100 m site the 10m water velocity was the average of water velocities collected 10 m from shore at O, 25, 50,75, and 100 m downstream from the start of the site.

Habitat preference histograms were developed using methods similar to those outlined by Baxter (1997). The weighted amount of habitat for each site was calculated by dividing the individual site lengths by the total length surveyed. Weighted habitat use was calculated the same way, by dividing the number of Arctic grayling captured at each site by the total number of Arctic grayling captured. A range and bin intervals were then selected, using the Sturges method (Cheslak and Garcia 1988) for depth and velocity at each distance from shore (1m, 5m, etc...) and the total habitat available in that range was calculated by adding up the weighted site values. Substrate values were averaged for the site rather that distance from shore.

Habitat preference was calculated by dividing habitat use (sum of the weighted site habitat use values) by habitat available. The values were then "standardised" by dividing the habitat preference values by the highest preference value. The value for habitat parameters then ranged from 0.0 to 1.0, with a value of 1.0 as the most frequently used habitat and 0.0 as unused habitat (Bozek and Rahel 1992). Habitat preference values were also calculated by multiplying the depth and velocity values for each site to generate a descriptive index. These values were used to determine if a single characteristic or a combination of characteristics was more important to Arctic grayling habitat selection. Only measurements out to 5 m from shore were examined for the comparison of age 0+ Arctic grayling habitat since young-of-the-year Arctic grayling prefer the shallow, near-shore waters (Armstrong 1986). Habitat characteristics out to 15 m from shore on the Parsnip River were compared for age 1+ Arctic grayling.

Adult Abundance Estimates

Adult abundance estimates for sport fish (Arctic grayling, rainbow trout and bull trout) were conducted on the Table and Anzac Rivers between July 27 to August 27,1998. Three sites on the Table River (km 35-31, km 22-18, km 9-5) and 5 sites on the Anzac River (km 47-45, km 43-39, km 34-30, km 16-12, km 10-6) were surveyed. Kilometre locations were marked on the rivers during previous surveys (Zemlak and Langston 1996, Blackman 2002 in prep) using interpolated data taken from the B.C. Provincial Watershed Atlas. These locations are approximate and distances between kilometre markers may change from year to year because of channel movements.

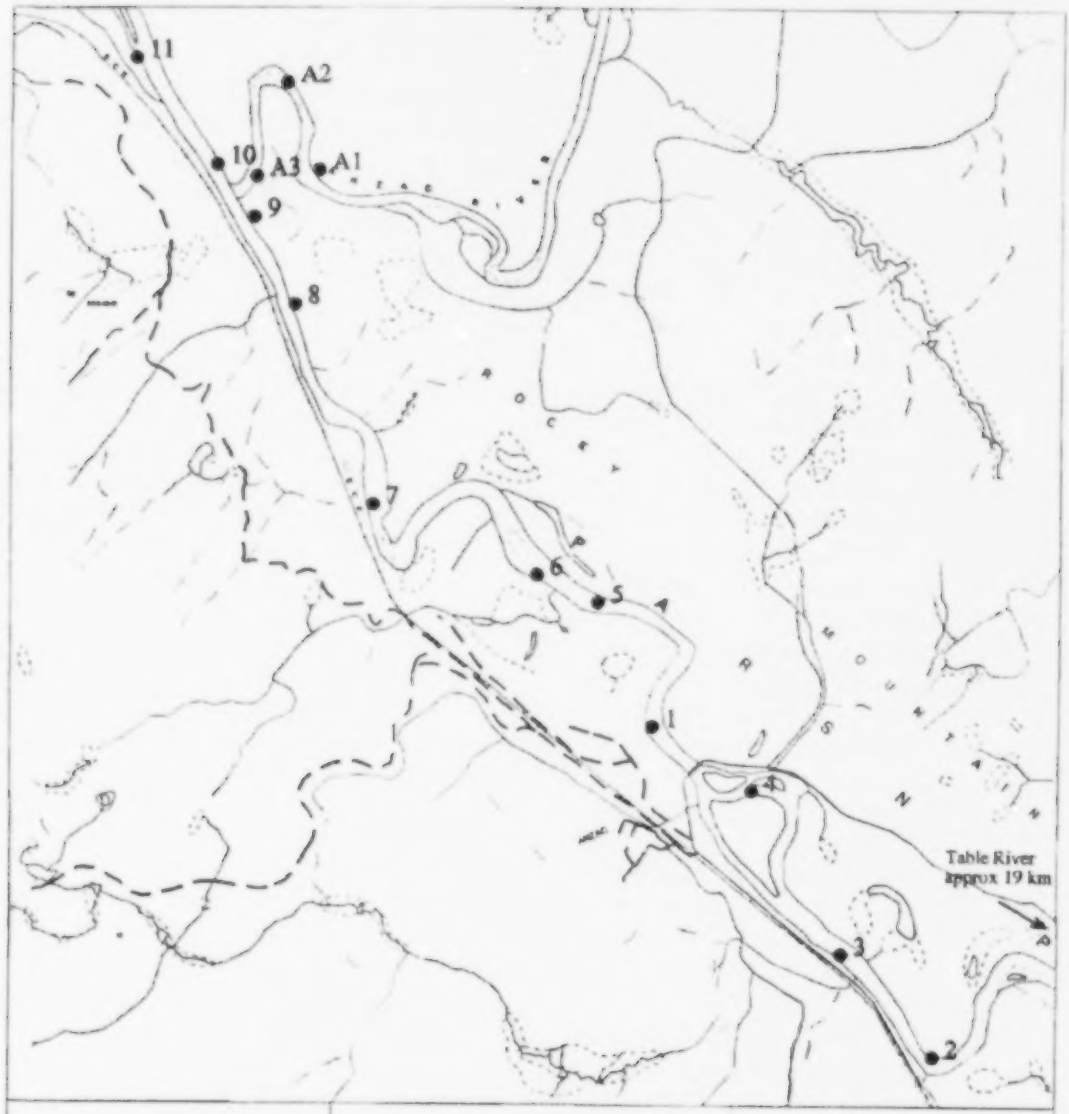

Figure 2: Beach Seining Sites on the Parsnip & Anzac Rivers

Albers Projection
NAD 83

Produced by
BC Environment,
Omineca Region GIS Section
March 26, 1999

0.5 km

BC Environment

British Columbia

Legend

- Seining Site
- Road Network
- Water Network
- Islands
- Marsh or Swamp

Adult abundance estimates were developed using mark recapture techniques. Arctic grayling, rainbow trout, and bull trout were captured by angling, in a 2-km section in the middle of each site. All fish greater than 200 mm were marked with spaghetti tags, sampled and released. Half of the Arctic grayling over 330 mm had both a scale and fin ray sample taken to compare ageing techniques. Fish under 200 mm were not floy tagged. All Arctic grayling were implanted with a PIT tag and were adipose clipped. Different coloured tags were used for each site. A swimmer was employed at some sites to locate fish and to determine if a minimum of 20% of the fish were tagged to insure the validity of the population estimates (Vincent 1971).

As soon as possible after tagging was completed , two underwater counts were conducted for each 4-km swim site, the tagging or study section plus 1 km both upstream and downstream. The counts followed similar methodologies to those outlined by Slaney and Martin (1987). Based on the underwater visibility and the wetted width of the site, (measured using an Eslon measuring tape and laser range finder) 2 to 4 swimmers conducted the underwater counts. Usually, the wetted width and the visibility made it necessary to have only 3 swimmers in the water. Each swimmer was assigned a lane, and recorded the number of fish of each species tagged and untagged, and the size range of all fish seen in that lane. Size ranges were based on 10 cm intervals (0-10, 11-20, 21-30, 31-40, 41-50 and 50+). On the second swim, swimmers changed lanes. In some instances different swimmers conducted the second pass. If time permitted, the second swim was completed on the same day; if not, then the second swim was completed on the following working day.

Some pools were encountered with large numbers (>50) of fish. These pools often had high water velocities in the middle and back currents near shore that made it impossible for the swimmers to obtain accurate counts while maintaining lanes. In these cases, the swimmers walked back to the top of the pool and swam back through in single file (usually in the middle or right lane). This was possible because underwater visibility and the positioning of the fish enabled the swimmers to see all of the fish. The first swimmer, counted tagged Arctic grayling, the second swimmer counted untagged Arctic grayling, and the third swimmer counted all other fish. This was repeated several times until a consensus was reached as to the number of fish in the pool. The data was recorded for the middle or most appropriate lane.

One crewmember walked the 4-km section with the swimmers to record wetted widths every 200-m (to estimate total wetted area), fish counts after each km, and to ensure swimmer safety. In the canyon section of the Anzac River (uppermost section), a helicopter was used to ensure swimmer safety. In two sections, Anzac km 47-46 and Table km 9-5 wetted widths were not recorded. For these two sites, wetted widths were derived from data recorded on previous surveys (Blackman 2002 in prep, Zemlak and Langston 1998).

The abundance estimates were calculated for the 4 km swim site because up to 40% of the tagged fish that were observed had moved out of the 2 km tagging section. Expansion factors were calculated for any site where water clarity did not allow for stream bank to stream bank visibility. Correction factors, as detailed by Slaney and Martin (1987), were calculated for each sample site. The correction factor accounts for fish that were not seen.

Petersen mark-recapture abundance estimates for Arctic grayling, rainbow trout and bull trout were calculated using a 5% correction to account for hooking mortalities and tag loss. The calculation used was:

$N=(M+1)(C+1) / (R+1)$
where:
"N" = Population estimate;
"M" = number of tagged fish corrected for tag loss and hooking mortalities
"C" = number of fish observed;
"R" = the number of tagged fish observed.

To be statistically valid a minimum of 20% of the population (N) must be marked (M) and to avoid bias because of low numbers (MC> 4N).

The weighted average population estimate was calculated from the two (in one instance three) estimates (swims) using the following formula :

$$N_w = \frac{N_1(1/SeN_1^2) + N_2(1/SeN_2^2)}{1/SeN_1^2 + 1/SeN_2^2}$$

where:

"N_w" = weighted average population
"N_1" = estimated population #1
"N_2" = estimated population #2
"SeN_1" = standard error of estimate #1
"SeN_2" = standard error of estimate #2
"Se" = $(N^2 (C-R) / ((C+1)(R+2)))^{-2}$

Comparison of Ageing Structures

There could be a problem with ageing Arctic grayling using scales because the first annuli may be missing (McCart 1972, Tack 1975) or in older individuals, the annuli may become compressed (Roguski and Winslow 1969), which could result in an underestimate of age. In order to validate ageing methods a scale and fin ray sample were collected from 40 Arctic grayling (fork length >330 mm) and sent to a reputable commercial ageing lab (North/South Consultants Inc, Winnipeg) for age determination. A similar program was also conducted in 1997.

RESULTS

Temperature Records

Water temperatures recorded from the Parsnip River were nearly 3°C warmer than those from the Table and Anzac rivers in early June. The water temperatures at the lower sites on both the Table and Anzac Rivers averaged 1°C warmer than at the upper sites (Table 1) and the Parsnip River site was slightly warmer than either. The Table and Anzac rivers had reached a equivalent water temperature 1 1/2 months earlier in 1998 compared to 1997 (Fig. 3 and 4). Unfortunately the thermographs were not installed early enough in 1998 to determine when the

rivers reached 4°C, the temperature when Arctic grayling spawning is initiated (Armstrong 1986).

Table 1. Mean biweekly water temperatures from the Parsnip, Table and Anzac Rivers.

Date		Table R. Km 22.8 1998	Table R. 1997	Table R. Km3 1998	Parsnip R. Bridge 1998	Anzac R. Km 3 1998	Anzac R. Km3 1997	Anzac R. Km 6 1998
April	1-15		-0.3					
	16-31		0.3					
May	1-15		2.2					
	16-31		3.6					
June	1-15	9.4	4.5	10.4	13.2	10.5		10.4
	16-30	11.7	6.1	12.9	14.2	12.7		12.5
July	1-15	14.0	8.7	15.3	16.1	15.3	10.1	15.0
	16-31	15.5	10.5	16.5	17.2	16.7	12.0	16.6
August	1-15	15.2	13.2	16.0	16.6	16.0	13.8	15.0
	16-31	13.1	11.5	13.9	14.2	13.8	12.6	13.2
September	1-15	11.3	9.5	12.1	12.2	11.6	10.2	9.6
	16-30	8.6	7.7	9.3	9.2	8.8	8.2	6.3
October	1-15	4.5		4.9	5.3	4.7		4
	16-28	3.2		3.4	3.5	3.1		3.2

Egg Deposition Survey

The egg deposition surveys were conducted at a previously identified spawning area and on a date when spawning had occurred the previous year (Blackman 2002 in prep). No eggs or redds were discovered at the site on the Anzac River. Newly hatched fry were found at the Table River sites and therefore the egg deposition survey was stopped.

Fry Distribution Survey

The preliminary fry distribution surveys conducted from June 16 to 18, 1998 found Arctic grayling fry were 10-15 mm in length (newly hatched) and mountain whitefish fry were 20-28mm . Thirty-one sites (Appendix I) were surveyed and 791 fry were counted in the Table River and 40 in the Anzac River. Newly hatched (one alevin and one 11mm) Arctic grayling fry were observed at km 27 of the Table River, the upper most location where fry were observed on these dates. Low numbers of fry were observed up to km 20 on the Anzac River. A large number (600) of newly hatched fry were observed on the Table River at km 1. These fry were located along the margin of a shallow riffle area and many were unable to hold a position against the current and were gradually drifting downstream. Very few fry were observed at this location during the second survey.

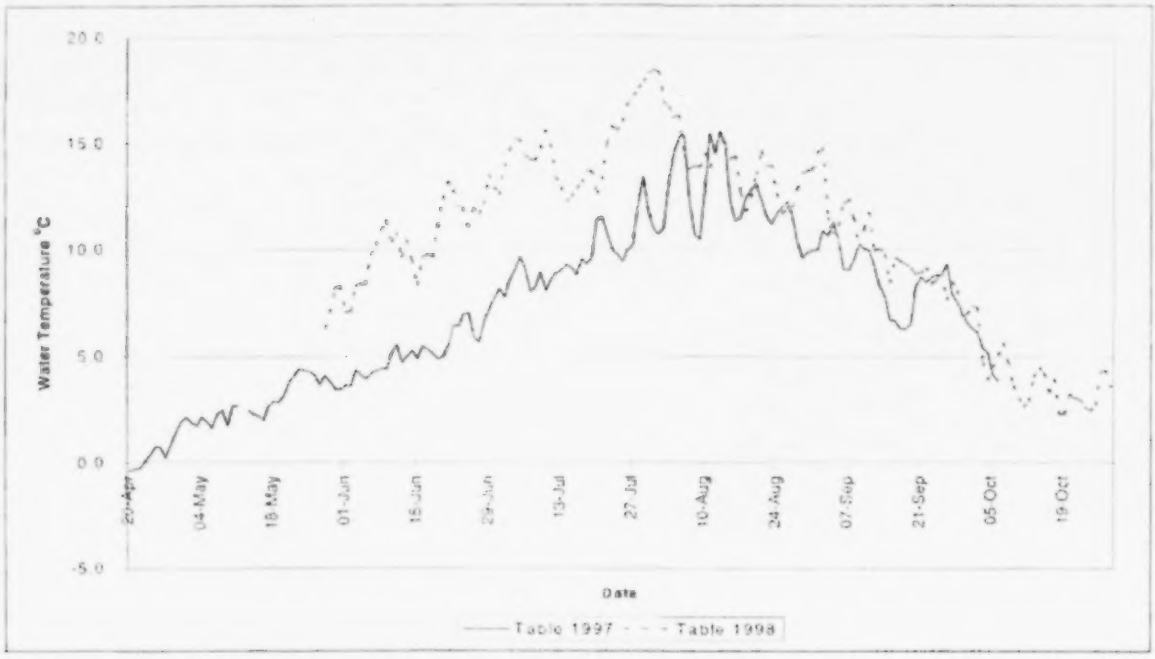

Figure 3. Table River mean daily water temperature data for 1997 and 1998.

Figure 4. Anzac River mean daily temperature data for 1997 and 1998.

Detailed fry distribution surveys started on June 30,1998 and three size groups of fry were observed. The smallest fry were 11 to 14 mm in length, and were little more than two eyeballs and a thread. Dense schools of these fry congregated in shallow, low velocity areas, which matches the description by Armstrong (1986) of newly hatched Arctic grayling fry. The medium sized fry, 15 to 25 mm in length, were more active and were found in slightly higher water velocity areas, as well as with the smaller fry. The largest of these fry (~25 mm) could be identified in the field as Arctic grayling by their larger dorsal fin. It was initially thought these two size groups were an early and late hatch of Arctic grayling. Morphological analysis of the fry by Dr. D. McPhail determined that the 15 to 25 mm fry were Arctic grayling, but the 11 to 14 mm fry were longnose suckers (Catostomus catostomus; Appendix I). Unfortunately, the field notes were not detailed enough to separate the Arctic grayling fry from the longnose sucker fry with any degree of certainty because frequently schools were a mixture of the two size groups. The third size group, larger than 25 mm were identified as mountain whitefish. Arctic grayling samples collected during this survey ranged from 15 to 25 mm in the Table River, with a tendency for the larger fry to be in the lower river. In comparison the samples collected from the Anzac River(one week later) ranged in length from 16 to 32 mm (Appendix I).

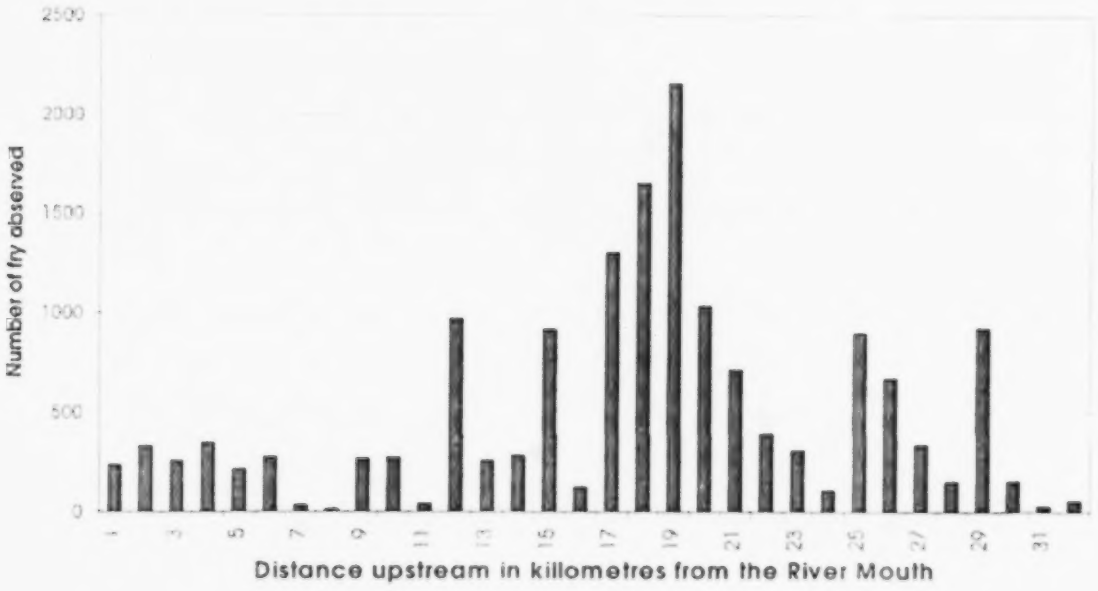

Figure 5. Total number of fry (Arctic grayling and longnose sucker) counted between kilometre markers on the Table River during the fry distribution survey

Fry were observed up to km 32 on the second survey. Most of the fry observed were located in alcoves, back channels and side channels (Appendix I). In these locations, fry were frequently seen in groups of 200, and several (5) schools were estimated at 500 to 1000. Fry

were also seen in small numbers (2-10 per school) in the slow moving waters found along the shoreline of gravel bars.

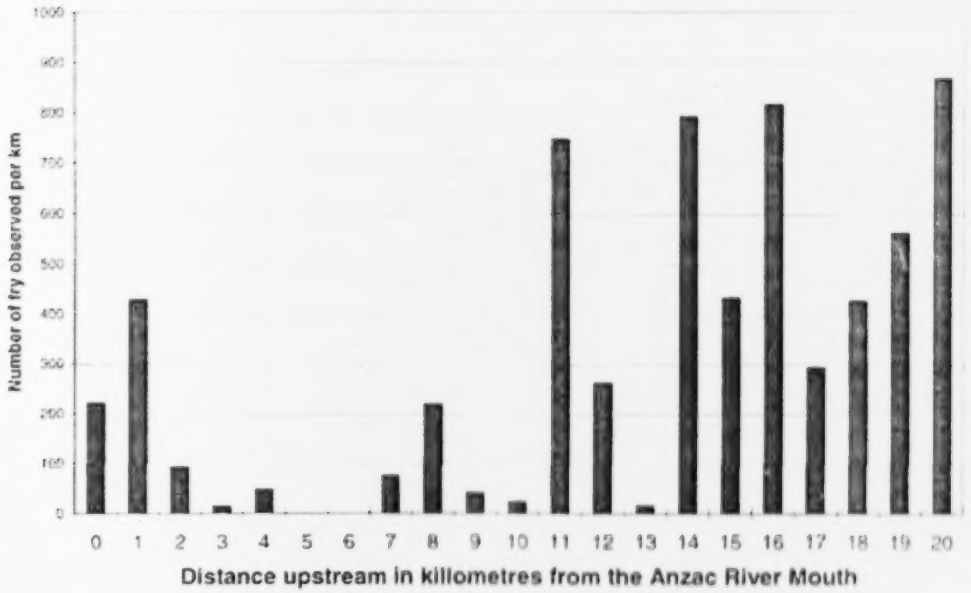

Figure 6. Total number of fry (Arctic grayling and longnose sucker) counted between kilometre markers on the Anzac River during the fry distribution survey

The fry count from the Table River was 14,250 with the highest numbers from km 17 to 20(Fig 5). There were also spikes in the counts at km 12, 15, 25 to 26, and 29 (Fig. 5). None of the specimens collected for morphological analysis upstream from km 25.5 were longnose suckers and therefore the 2, 000 fry counted from this point up to km 33 were probably Arctic grayling.

The fry count from the Anzac River was 5,278, with the highest numbers at km 1, 11, and from 14 to 20 (Fig 6). (The area from km 14-20 is multi channelled and radio telemetry and fry distribution studies conducted in 1997 concluded that this was the main spawning area (Blackman 2001). The survey did not extend further up the Anzac River in 1998 due to time and budgetary constraints and because utilisation of this area was low in the previous studies.

Young-of-The-Year Fall Rearing Densities

Fish density estimates were obtained using enclosed electrofishing sites at km 9.8 and km 22 of the Table River from September 1 to 3 in 1998. Twenty four mainstem bank sites measuring 3 x 25 meters, plus four whole river, and two side channel sites were sampled. The total area surveyed was 4,629 square meters or 850 linear meters. The 29 young of the year (0+)

Arctic grayling captured (Table 2) had an average fork length of 72.2 mm and an average weight of 2.42g.

Densities for Arctic grayling and total fish for the 3 m x 25 m shoreline sites, the mainstem sites and the side channel sites were greater at km 9.8 than km 22 (Table 3). The number of Arctic grayling and total fish per lineal meter of stream was approximately double in the mainstem (both banks) sites in comparison to the 3-m x 25-m shoreline sites (one bank). The estimated number of Arctic grayling fry was up to 40 per kilometre(two banks) at km 22 and 80 per kilometre at km 9.8. Arctic grayling were the most numerous sport fish species captured and no young of the year bull trout were captured.

Table 2 Fish species captured during the fall electrofishing sampling program

Species	Number	Mean Fork Length mm	Range	Mean Weight g	Range
Arctic Grayling	29	72.2	63-88	3.48	2.2-4.5
Bull trout	4	155.4	123-212	33.5	11.4-86.6
Burbot	9	136.4	76-173	16.2	4.3-28.9
Rainbow trout 0+	4	55.3	52-57	1.8	1.4-2.0
Rainbow trout 1+	7	126.3	89-141	18.2	6.8-29
Mountain Whitefish	5	75.5	66-80	3.5	2.3-4.6
Sculpins	640	51.9	24-87	1.7	0.1-7.5
Longnose Suckers	123	49.4	24-165	1.6	0.2-49.1

Table 3. Arctic grayling and total fish densities for the Table River at the bridge crossing (km 22) and the middle ford crossing (km 9.8) in shoreline, sidechannel and mainstem sites.

Site		Grayling			Total Fish		
		3x25m shoreline	Side Channel	Mainstem	3x25 m shoreline	Side Channel	Mainstem
Bridge km 22	fry per kilometre of stream	17	36	40	417	459	987
	Density (fry per hectare)	60	40	30	1390	500	690
Ford km 9.8	fry per kilometre of stream	37	62	80	1020	1880	2880
	Density (fry per hectare)	120	70	40	3400	2300	1600

Age 0+ and 1+ Arctic grayling Habitat Utilisation

On the first beach kilometre seining survey (July 14-17), 21 net sets at 10 sites were completed over an 8 km length of the Parsnip River, and 4 net sets at 3 sites over 3 km were completed on the Anzac River. This session captured 164 Arctic grayling, 19 rainbow trout, and

4 bull trout from the Parsnip River. The age composition of the Arctic grayling was: 85 age 0+, 55 age 1+, 18 age 2+, 5 age 3+, and 1 age 4+. Large numbers of age 0+ Arctic grayling were captured at Sites 5, 7 and 10 (Fig 2.); age 1+ Arctic grayling were caught primarily at Sites 9 and 10. An additional 67 Arctic grayling and 1 rainbow trout were caught in the Anzac River. Sixty-four of the 67 Anzac Arctic grayling were from the 0+ age class and were capture at Sites 1A and 3A. Three age 1+ Arctic grayling were also captured at these sites.

The second sampling survey (July 21 - 24), gathered additional habitat utilisation information. Twenty-three net sets at 11 sites were conducted, covering 2285m of stream or a total area of 45,700 m^2. Age 0+ Arctic grayling numbers captured by beach seine in the Parsnip River were 117, or about 50 per km, based on fishing only one bank. The young fry tend to utilise a narrow strip of low velocity habitat along the bank, as demonstrated in the electrofishing survey contained in this report and in habitat utilisation studies conducted on these streams in 1997 (Blackman 2002 in prep) so a linear description of numbers seems most appropriate. Fifty four one year old grayling were captured, or 25 per km but because these fish primarily occupy the middle of the stream channel a more appropriate description would bet would be 11 ha^{-1}. Twelve age 2 and six age 3 Arctic grayling, 19 rainbow trout, and 9 bull trout were also captured. An additional 18 age 0+ and 1 age 1+ Arctic grayling fry were caught in the Anzac River from 4 net sets at 3 sites covering an area of 9,500 m^2.

The third sampling session, conducted from September 8 to 10 at the same sites, captured a total of 192 Arctic grayling, 16 rainbow trout, and 15 bull trout from the Parsnip River. The age composition of the Arctic grayling was, 159 age 0+, 27 age 1+, 1 age 2+, 2 age 3+, 2 age 4+ and 1 age 5+. The total number of grayling that were PIT tagged was 188. No Arctic grayling, rainbow trout or bull trout were caught at Site 3A, the only accessible site, on the Anzac River.

Beach seine sets were 25 to 195 m in length. Water depth ranged from 0.04 m close to shore to 1.58 m, 15 m from shore; velocities ranged from 0.00 m/s to 1.33 m/s. The number of Arctic grayling captured per set ranged from O to 33 age 0+ and 0 to 11 age 1+ (Appendix III). Substrate composition ranged from cobbles to fines (Appendix III). Habitat types covered in the two rivers ranged from wide, deep, slow moving sections of the river with a high fines content (50%), to narrow river sites with shallow, swifter flowing water over a gravel (85%) substrate, to sites that had slow, shallow water over a mixed gravel and cobble substrate. Data from site 10 A was not used during the analysis of habitat preference because it was not typical of most habitats on the Parsnip River. Site 10 A was located in the Parsnip River immediately downstream from the mouth of the Anzac River. The water at this site was clearer and probably cooler (variables we were not measuring) than any other site on the Parsnip River.

Young of the year Arctic grayling showed a strong preference for sites where water depth was less than 0.06 m one meter from shore and where velocities were less than 0.03m/s. (Fig 7.).

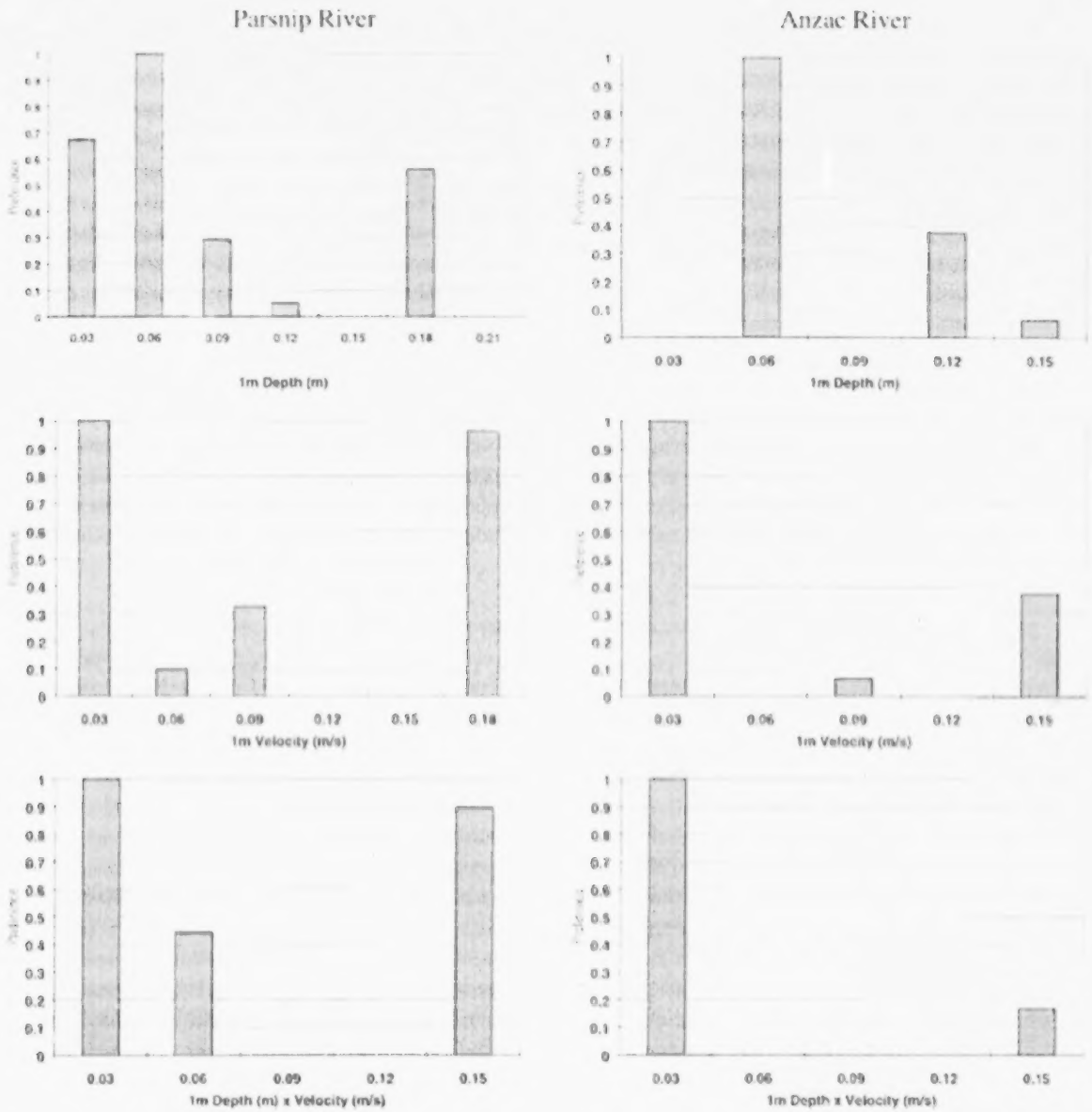

Figure 7. Habitat (site) preference of age 0+ Arctic grayling fry in the Parsnip (left) and Anzac Rivers (right) from depth and velocity measurements taken one meter from shore. Preference is based on habitat use / habitat available, where habitat use =the total number of fry captured from a habitat (depth or velocity) bin / the total number of fry captured, and habitat available = the length of stream that falls within a habitat (depth or velocity) bin / the total length of stream sampled. Habitat preference in this case suggests that more fish were captured in sites, which had certain habitat characteristics.

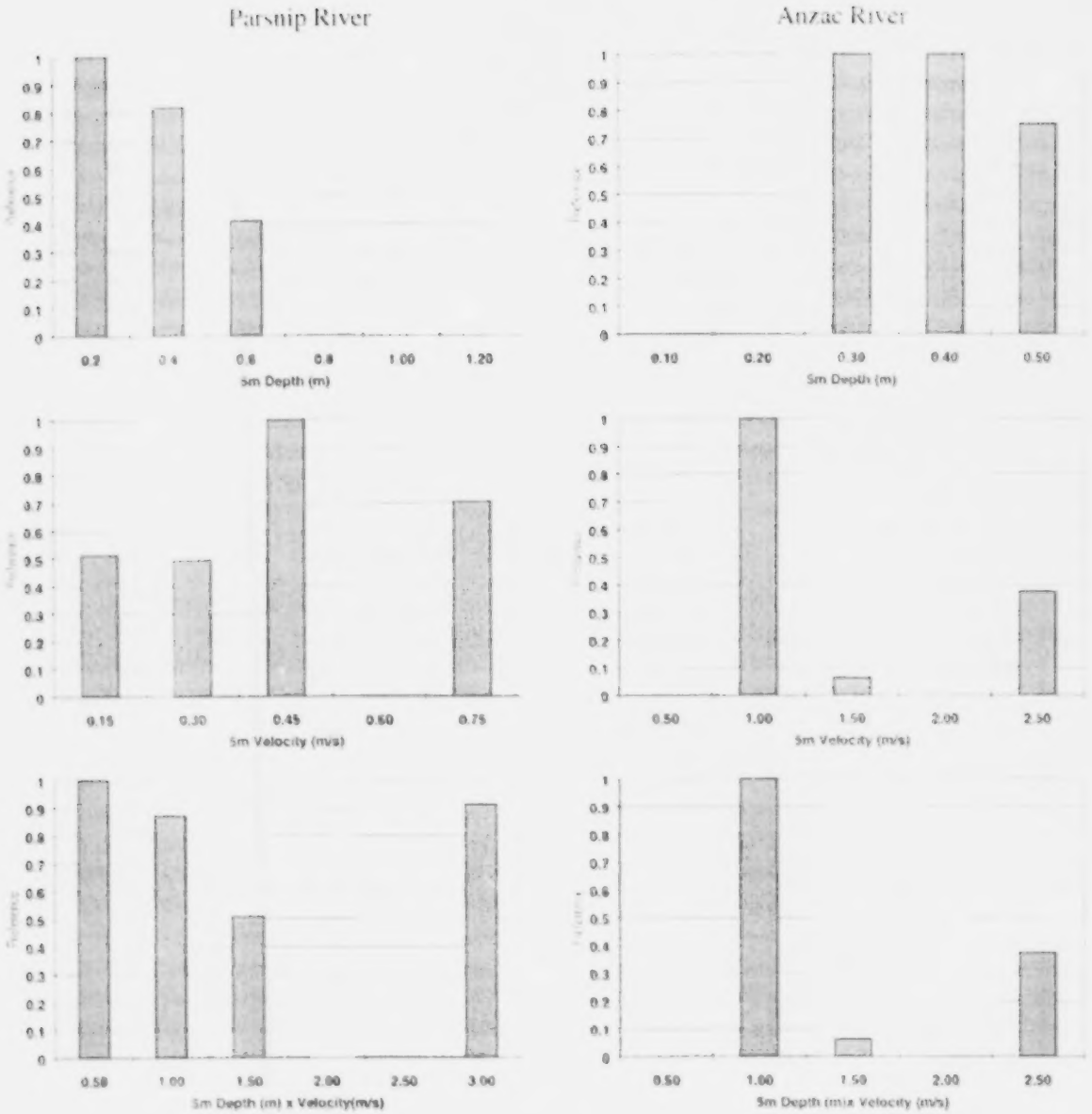

Figure 8 Habitat (site) preference of age 0+ Arctic grayling fry in the Parsnip (left) and Anzac Rivers (right) from depth and velocity measurements taken 5 metres from shore. Preference is based on habitat use / habitat available, where habitat use =the total number of fry captured from a habitat (depth or velocity) bin / the total number of fry captured, and habitat available = the length of stream the falls within a habitat(depth or velocity) bin / the total length of stream sampled. Habitat bins are based on the range of the parameter and the sample size.

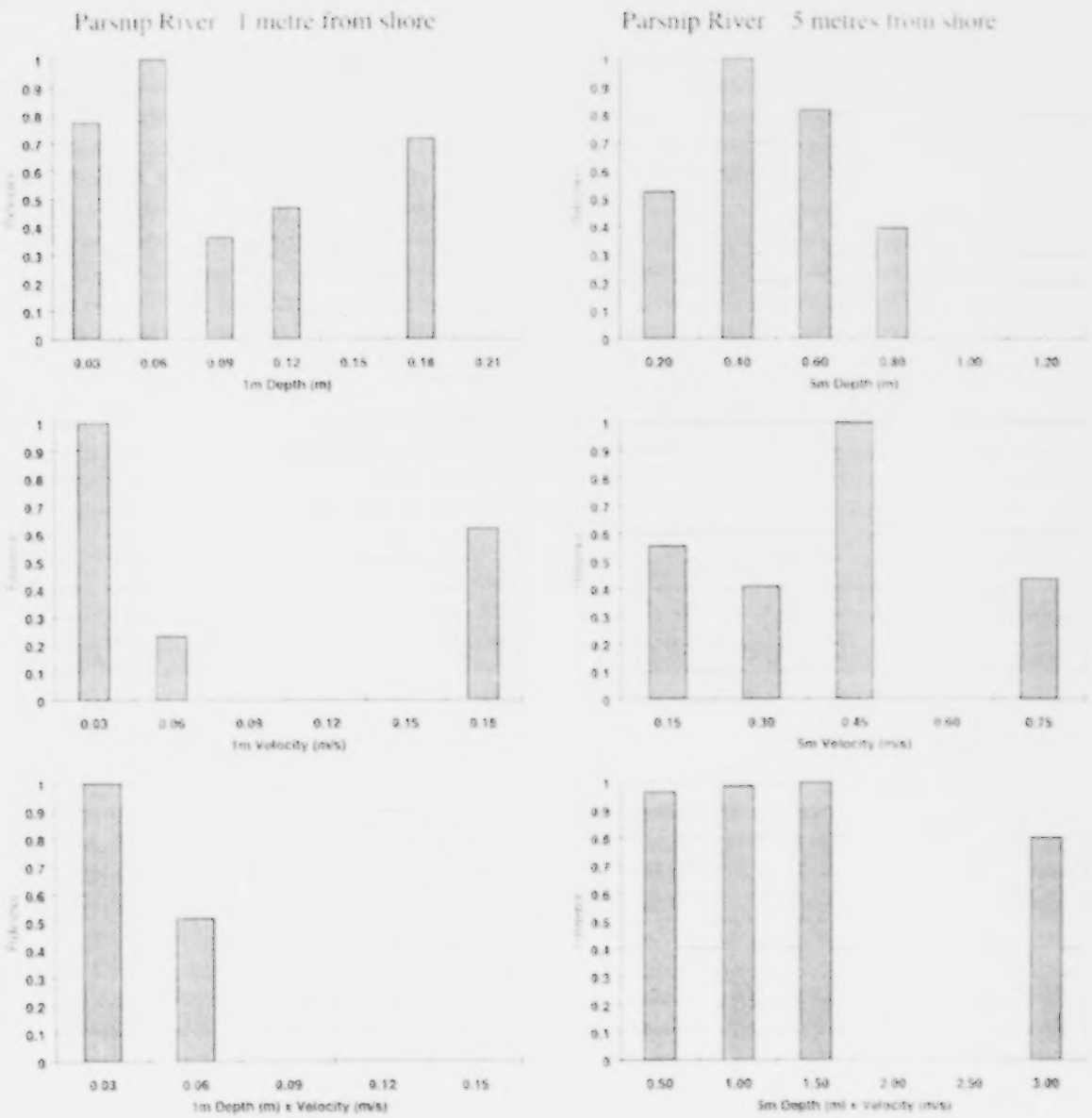
Parsnip River 1 metre from shore
Parsnip River 5 metres from shore
1m Depth (m)
5m Depth (m)
1m Velocity (m/s)
5m Velocity (m/s)
1m Depth (m) x Velocity (m/s)
5m Depth (m) x Velocity (m/s)

Figure 9 Habitat (site) preference of age 1+ Arctic grayling fry in the Parsnip River from depth and velocity measurements taken one and 5 metres from shore. Preference is based on habitat use / habitat available, where habitat use =the total number of fry captured from a habitat (depth or velocity) bin / the total number of fry captured, and habitat available = the length of stream the falls within a habitat(depth or velocity) bin / the total length of stream sampled. Habitat bins are based on the range of the parameter and the sample size. Habitat preference in this case suggests that more fish were captured in sites, which had certain habitat characteristics.

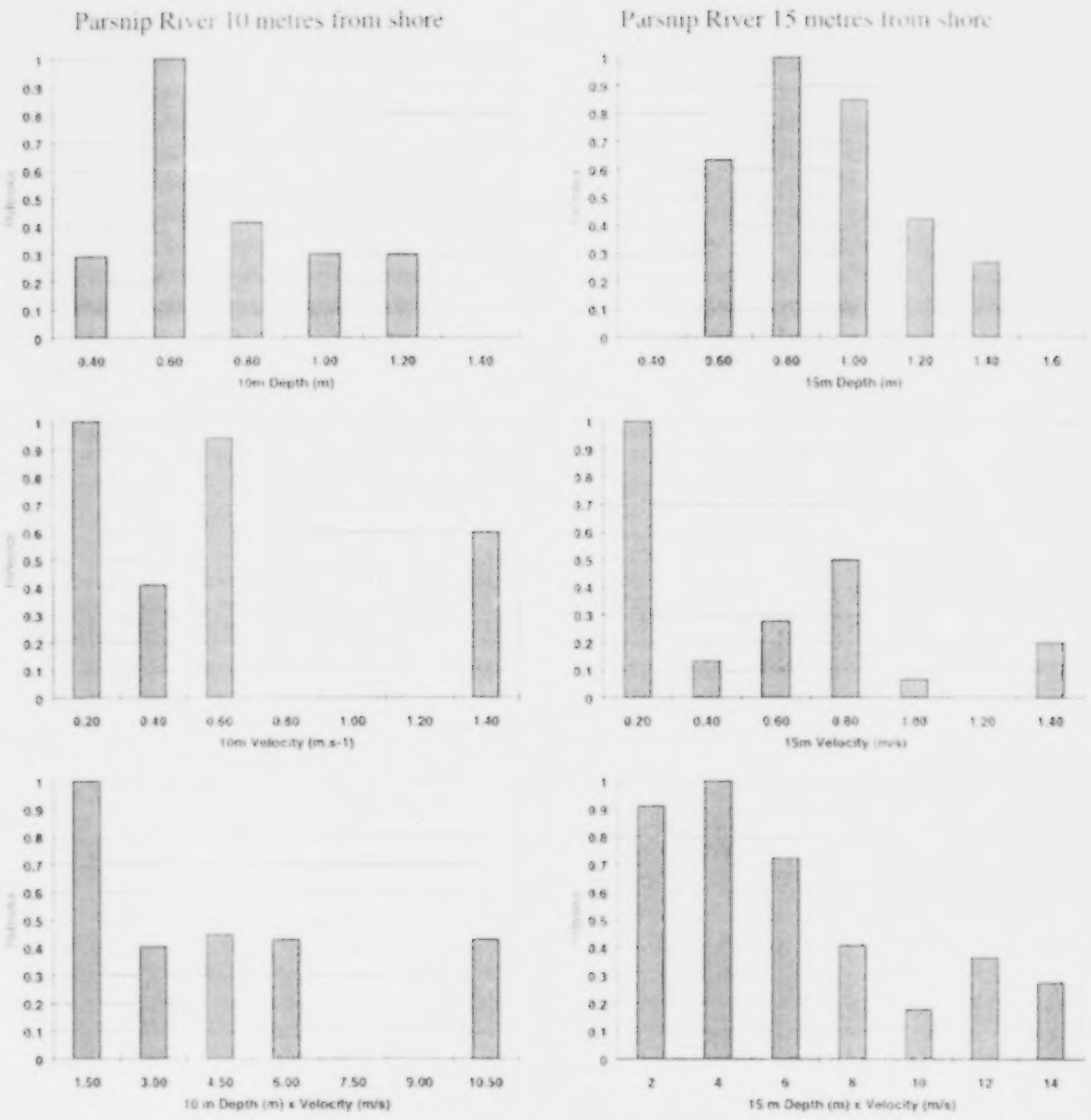
Parsnip River 10 metres from shore
Parsnip River 15 metres from shore
10m Depth (m)
15m Depth (m)
10m Velocity (m.s-1)
15m Velocity (m/s)
10 m Depth (m) x Velocity (m/s)
15 m Depth (m) x Velocity (m/s)

Figure 10 Habitat (site) preference of age 1+ Arctic grayling fry in the Parsnip River from depth and velocity measurements taken ten and fifteen metres from shore. Preference is based on habitat use / habitat available where habitat use =the total number of fry captured from a habitat (depth or velocity) bin / the total number of fry captured, and habitat available = the length of stream the falls within a habitat (depth or velocity) bin / the total length of stream sampled. Habitat bins are based on the range of the parameter and the sample size. Habitat preference in this case suggests that more fish were captured in sites, which had certain habitat characteristics.

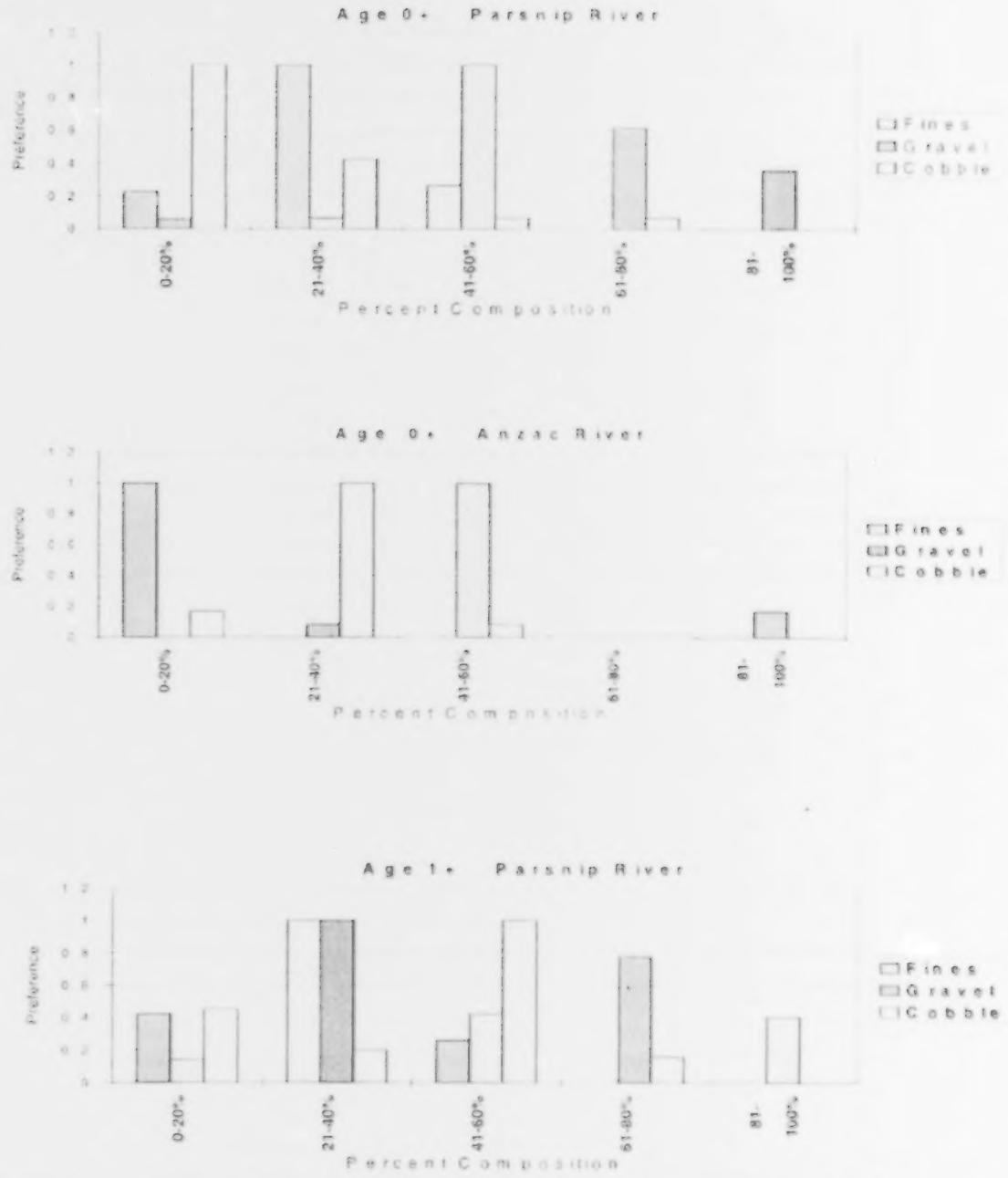

Figure 11. Habitat preference of age O and 1+ Arctic grayling fry in the Parsnip and Anzac rivers from substrate measurements.

Age 1+ Arctic grayling were most frequently captured in sites with a depth of 0.21-0.60 m and a velocity of 0.45 m/s, five meters from shore (Fig 9.). There was a strong preference for sites with a 10m depth of 0.41-0.60 m and fifteen m depths between 0.41 and 1.0m. Sites with low velocities (0.20m/s) ten to fifteen metres from shore were also preferred (Fig 10.)

Substrate preferences may be a result of velocity preferences with fry showing a preference for sites with 21-40% fines, 41-60% gravel and O to 20% cobble (lower velocity areas) in the Parsnip River. But in the Anzac River the preferred sites had 0-20% fines (no sites had greater than 20% fines), 41-60% gravel and 21-40 % cobble.(Fig 11.) The one year old juveniles captured in the Parsnip River showed a preference for sites with a fines content of 21-40%, 21-40% gravel and 41-60% cobble.

Adult Abundance Estimates

Spaghetti tags were used to mark 122 Arctic grayling, 21 bull trout, and 86 rainbow trout in the study sections of Table River, and 206 Arctic grayling, 16 bull trout, and 48 rainbow trout in the study sections of Anzac River. In both rivers the numbers of Arctic grayling, bull trout and mountain whitefish observed per kilometre during the underwater counts was much higher in the upper reaches than in the lower. Rainbow trout were evenly distributed throughout the Table River but were relatively sparse in the upper and lower reaches of the Anzac River (Table 4).

Table 4. The number of fish observed per kilometre of stream.

River	Table			Anzac				
Reach	1	2	3	1	2	3	4	4
Km	9-5	22-18	35-31	10-6	16-12	34-30	42-39	47-45
Arctic grayling	<1	17	30	4	2	23	33	82
Bull trout	3	5	27	<1	0	3	4	11
Rainbow trout	11	15	18	<1	9	8	2	2
Mountain whitefish	1	26	223	<1	<1	2	108	92
Total	16	63	298	6	12	36	147	187

* average of the counts for fish > 20 cm fork length

Abundance estimates were up to 94 Arctic grayling, 66 rainbow trout and 84 bull trout per kilometre (Appendix II). The numbers of tagged fish observed were highly variable, ranging from O to 100% (Table 5). In the Table River, 68 of the 122 tagged Arctic grayling were observed during the counts. However, 12 of the tagged fish were observed outside of the tagging (2-km) area, and one fish tagged in Reach 2 was recaptured by angling in Reach 1. In the Anzac River 153 of 206 tagged Arctic grayling were observed but 28 were outside the tagging area (Table 5).

Comparison of Ageing Structures

Ninety samples were collected to compare fin ray and scale ages during 1997 and 1998. The Arctic grayling used for ageing structure comparisons ranged in size from 311 to 400 mm FL with an average of 350 mm. Thirty three fish were found to be the same age and an additional forty five were within one year using both ageing techniques. Scales tended to underestimate age particularly in older fish (Fig 12).

Age Class Distribution of Arctic grayling

The Arctic grayling population utilising the Anzac River during the summer was slightly larger at a given age (Table 7) and is composed of more individuals in the older and larger age classes than the population of the Table River (Fig 13). Very few Arctic grayling younger than four years have been captured in the Anzac River. Two and three year old Arctic grayling are fairly common in the Table River and limited sampling (beach seines) of the Parsnip River in 1998 year found younger age groups to be predominant (although efforts to capture larger adults were limited).

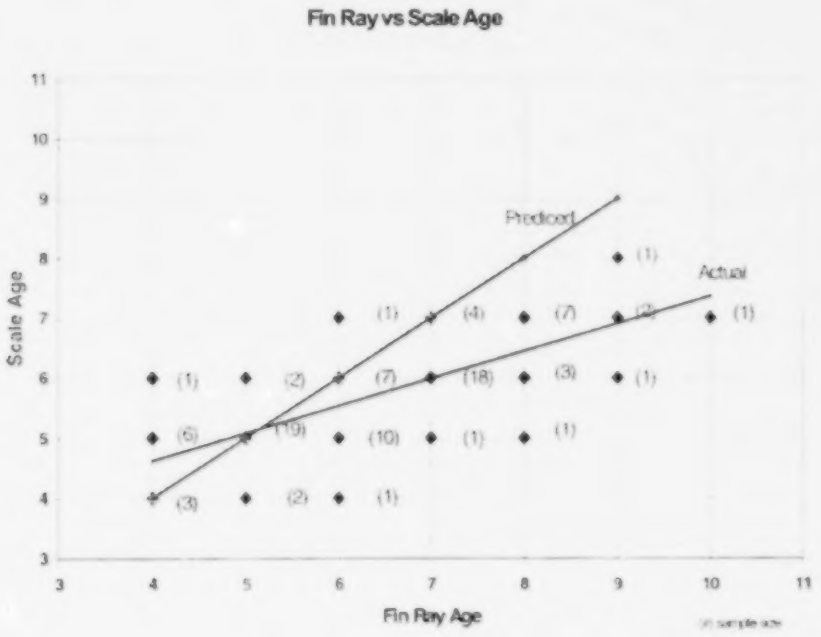

Figure 12. Comparison of fin ray age vs. scale age from samples collected from the Table and Anzac Rivers in 1997 and 1998. The numbers on the graph represent the number of fish in each age category, as determined from scales and fin rays. The trendlines indicate that as age increases the difference between scale and fin ray ages increases

Table 5. **Observations and movements of tagged fish during the underwater counts on the Table and Anzac Rivers.** The percentage of tagged fish that moved out of the marking area was highly variable. It is unknown if the tagged fish that were not observed had left the area completely or were missed by the swimmers. The "swim" includes all tags observed in the 4 km section including the 2km"tagging' section. The "marks moved" is the percentage of the observed tagged fish that had moved out of the 2km tagging or study section. Water conditions were ideal during the surveys with an average underwater visibility of 6m.

													Grayling			Bull Trout			Rainbow trout		
						Swim							% marks		%	% marks			% marks		%
River	Km	Tagging	No. Tagged			Date	GR(m)		BT(m)		RB(m)		Observed		Marks	observed		marks	Observed		marks
		Date	GR	BT	RB		swim	study	Swim	Study	Swim	study	Swim	study	Moved	swim	study	moved	swim	Study	moved
Table	9-5	A7&11	7	1	43	Aug-12	0	0	0	0	8	8	0%	0%		0%	0%		19%	19%	0%
	4000m		7	1	43	Aug-12	0	0	0	0	6	6									
Table	22-18	J27&28	35	1	10	29-Jul	17	11	0	0	2	2	49%	31%	35%	0%	0%		20%	20%	0%
	4000 m		35	1	10	29-Jul	15	9	0	0	1	1	43%	26%	40%	0%	0%		10%	10%	0%
Table	35-31	A5&6	80	19	33	Aug-07	51	45	6	4	17	17	64%	56%	12%	32%	21%	33%	52%	52%	0%
	4600m		80	19	33	Aug-10	41	36	4	3	4	4	51%	45%	12%	21%	16%	25%	12%	12%	0%
Anzac	10-6	A 24	4	0	3	25-Aug	0	0	0	0	1	1							33%	33%	0%
	3600m		4	0	3	25-Aug	0	0	0	0	1	1							33%	33%	0%
Anzac	16-12	A20	1	0	11	20-Aug	0	0	0	0	4	4							36%	36%	0%
	3250 m		1	0	11	21-Aug	0	0	0	0	1	1							9%	9%	0%
Anzac	34-30	A11-13	65	12	28	Aug-13	36	29	9	7	11	11	55%	45%	19%	75%	58%	22%	39%	39%	0%
	4450 m		65	12	28	Aug-14	28	25	2	2	11	11	43%	38%	26%	17%	17%	0%	39%	39%	0%
	Six additional tagged grayling observed in pool immediately below the swim area																				
Anzac	42-39	A18&19	48	3	2	Aug-19	28	19	1	0	1	1	58%	40%	32%	33%	0%	100%	50%	50%	0%
	3940m		48	3	2	Aug-19	40	27	3	3	0	0	83%	56%	33%	100%	100%	0%	0%	0%	0%
			48	3	2	Aug-19	46	26	3	3	1	1	96%	54%	43%	100%	100%	0%	50%	50%	0%
Anzac	47-45	A 26-27	88	1	4	27-Aug	74	74	0	0	0	0	84%	84%	0%	0%	0%		0%	0%	0%
	2000m		88	1	4	27-Aug	70	70	0	0	2	1	80%	80%	0%	0%	0%		50%	25%	25%

Swim = 4km
Study (tagging) = 2 km

Table 6. Comparison of Table and Anzac River Arctic Grayling growth rates from samples collected from 1995 to 1998.

Age	2	3	4	5	6	7	8	9
	Table River Arctic grayling							
Mean F.L.	180.2	252.2	293.9	325.2	344.3	350.5		
SD	15.4	18.3	19.8	18.8	19.9	11.5		
No.	10	53	83	94	46	9		
	Anzac River Arctic grayling							
Mean F.L.		283.9	310	337.3	347.0	362.9	368.7	367.3
SD		18.9	18.6	18.5	20.3	16.0	17.9	16.6
No.		17	67	81	57	28	15	3

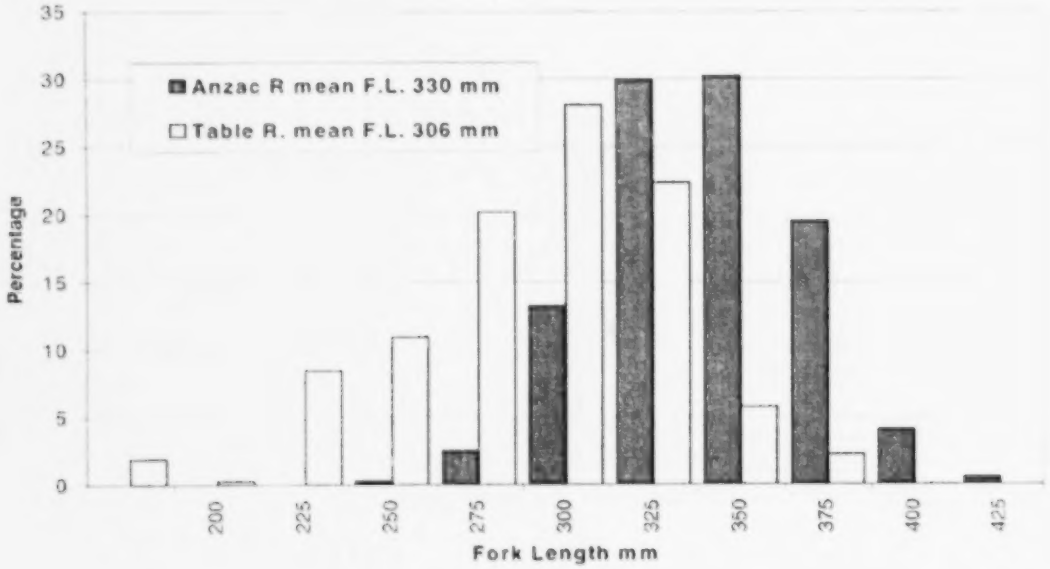

Figure 13. Arctic grayling length frequency distribution from the Table and Anzac Rivers (1995-1998, sample size 768). X axis values are the maximum value in size category.

Pit Tag Retention and Juvenile Growth

During fall beach seining nine previously tagged Arctic grayling were recaptured; 8 juveniles (age 1+) and 1 adult. Four of the eight Arctic grayling juveniles were missing PIT tags. The four recaptured Arctic grayling juveniles had been implanted on July 14, 15, 22 and 23. Growth over this period ranged from 7 to 11 mm (mean 10 mm) and 1.3 to 4.1 g (mean 3.15 g). One of the four recaptured Arctic grayling juveniles had moved one site (~ 350 m) downstream but the others were recaptured at the original tagging sites. An adult Arctic grayling which had been tagged on the Table River at km 33.5 on August 6th 1998, was recaptured at Site 9B on the Parsnip River on September the 6th (58 km downstream).

In July the mean fork length of the 0+ Arctic grayling captured from the Parsnip River was 49.7 mm with a range of 34 to 67 mm. The Anzac River fish were statistically smaller ($P<_{0.005}$) with an average fork length of 41.3 mm and a range of 32-61 mm. One year old Arctic grayling from the Anzac River were also smaller ($P<_{0.05}$) with an average fork length of 104 mm (range 100-110) compared to 114 mm (range 110-146) from the Parsnip fish.

The average growth rate of all age 0+ Arctic grayling on the Parsnip River from July to September was 27.6 mm and 2.74 g. The average length and weight of age 0+ Arctic grayling in July (July 14-17 sampling session) were 47.7 mm and 1.11 g. The averages in September were 75.3 mm and 3.85 g.

The average lengths and weights of 1+Arctic grayling juveniles captured in the first seining session were 111.6 mm and 13.76 g. This increased to 122.8 mm and 16.89 g in September.

DISCUSSION

Temperature Records

The Table and Anzac Rivers were warmer in 1998 compared to 1997(Fig. 3 and 4). In 1998, the Anzac River was the same temperature (7.26°C) on May 29 as it was on June 26, 1997 (7.31 °C). This was attributed to the low snow pack by the end of the winter, lower than normal precipitation and higher air temperatures. Accumulated valley-bottom precipitation from January 1st to March 1st was 75% of normal; mean daily air temperatures from February 1st to June 1 were 1°C to 4°C higher than normal (B.C. Environment Website). These factors resulted in a decrease in water flows and an increase in water temperatures.

The lower flows and warmer water temperatures in 1998 resulted in a one month advance in the Arctic grayling fry emergence dates in comparison with 1997. Warmer water temperatures or longer growing seasons may also explain why the Arctic grayling fry were larger in the Parsnip River than in the Table or Anzac. Fry emergence was also earlier in the lower Table River than in the upper river, which was one degree colder in early June (Table 1). It has been suggested by Stein (1973) that water temperature itself does not dramatically affect Arctic grayling growth but rather the length of the growing season (warm temperatures early) is most important in determining first year growth. However more detailed and long term temperature / growth data will be required to verify this.

Egg Deposition Survey

It would be highly advantageous to be able to determine the number of spawners, egg deposition and egg to fry survival rates for this species. However, the methods used may not be the most suitable, In 1998, Arctic grayling fry started to emerge in early June (one month earlier than in 1997), before the crew was in the field. The low numbers of Arctic grayling fry observed near the egg deposition survey area (Appendix I), suggests that either there were very poor egg to fry survival rates or the fish may have spawned at a different location. More extensive studies

were conducted on the Sukunka River (a nearby system) in 1978 and these surveys also failed to find any eggs (Stuart and Chislett 1979).

This methodology does not appear to have a favourable potential because of the difficulty in finding redds and the possibility that spawner distribution and emergence times may change with yearly flow variations.

Young-Of-The-Year Fry Distribution

The June 7th to 17th surveys were able to distinguish Arctic grayling fry from mountain whitefish, but the numbers observed were so low that most spawning locations could not be identified. The surveys started two weeks later located many more fry but the grayling were mixed with longnose sucker fry, which were not observed in large numbers in 1997 (Blackman 2002 in prep). The presence of large numbers of sucker fry makes the data collected this year inconclusive for determining relative fry abundance and spawner distributions. The exception was the upper Table River beyond the range of the suckers, where fry concentrated at km's 25, 26 and 29. Arctic grayling fry were distributed up to km 32.6 in 1998. In previous studies (Mathias et al 1998, Zemlak and Langston 1998, Blackman 2002 in prep), no Arctic grayling fry had been captured upstream from km 27. This change in distribution may have been affected by the lower spring runoff.

The surveys conducted on the Anzac River did not extend upstream as far in 1998 as in 1997 because of budgetary constraints. Counts potentially underestimated the total number of fry that emerged from km 14 to 20 because many of the channels, where fry had been observed in 1997, were dry or were rapidly drying out at the time of the survey in 1998. We suspect that a high percentage of the 1998 Anzac fry perished soon after hatching in this section of the river through stranding.

Under the proper conditions this method of counting newly hatched fry along the stream margin could provide a cost-effective way of locating areas with high spawner use. During the detailed surveys, where all possible areas were searched, two crews surveyed approximately 10 km of stream per day. However, this method has several critical weaknesses. Fry may drift or be swept downstream soon after hatching. Weather conditions are very important for the success of such a survey. High winds, rain or even overcast conditions make the observation of fry very difficult.

The timing of the surveys is also critical. The early survey (June 16 to 18, 1998) was conducted only a few days after the Arctic grayling had started to emerge in the lower Table River, but before they had started in the upper river. Two weeks later, after most of the fry had emerged, some of the first fish to emerge had dispersed and counts were complicated by the number of longnose sucker fry present. This methodology is probably only suitable during the first 10 to 14 days after emergence. Fry become much more difficult to observe as they get older. Newly hatched fry were observed to hold in midwater or near the surface but as the fry grow they appear to become more closely associated with the bottom and to hide in the substrate or more frequently dart into deeper water when disturbed.

The size ranges of the fry collected (Table River 15 to 25 mm; Anzac River 17-32 mm) in late June and early July indicates a substantial spread in emergence dates. Stuart and Chislett (1979) reported Arctic grayling fry in the Sukunka River, an adjacent drainage, were 14 mm on emergence, 24 mm after 20 days growth, and 28 mm after 28 days.

As the fry grow, they are more mobile, more difficult to observe and potentially could disperse from the spawning areas. Most authors (Stuart et al 1982, McCart et al 1972, Jessop et al 1973, MacPhee and Watts 1973, Trip and McCart 1974, Craig and Poulin 1975) report that Arctic grayling remain near the spawning areas for the first few months, but pronounced downstream movements have been reported (Kratt 1977, Nelson 1954, Kruse 1958, deBruyn and McCart 1974). What triggers these patterns is not known, therefore, the timing of this type of fry distribution survey is critical. Too early and all of the fry may not have hatched; too late and fry may move or be displaced. This would suggest that even under ideal conditions, a minimum of two surveys would need to be conducted to locate all spawning areas.

The size of the Arctic grayling fry sampled during the surveys indicates hatching occurred from June 10th to June 25th in 1998, roughly the same time that the peak of spawning was occurring the previous year (Blackman 2001). Surveys should probably start roughly 175 to 200 degree-days after water temperatures first reach 4°C (the temperature that appears to trigger spawning) rather than on predetermined dates. It is not known if spawning distributions will change with different water conditions but the fry distribution patterns are different in these systems in different years. Identification of newly hatched fry is difficult if longnose sucker fry are present but a key (Appendix IV) has been developed to make this less of a problem.

Young-Of-The-Year Fall Rearing Densities

The 1998 Table River rearing densities of Arctic grayling at the index sites ranged from 34 to 80 fry per kilometre or 30 to 120 Arctic grayling per hectare in prime habitat. The numbers of fry per linear kilometre of stream were approximately double (36 to 80) in the mainstem sites (two shorelines) when compared with the 3 x 25 m shoreline sites (17 to 37), which is what would be expected if all the fry were rearing along the shoreline. This supports the findings of Armstrong (1986) and Vascotto (1970) who found that young of the year Arctic grayling utilise the shallow near shore areas. These numbers appear to be very low but Stuart et al (1982) reported combined rearing densities of age 0+ to 3+ Arctic grayling to be 30 to 60 Arctic grayling per hectare in Adsett Creek in North Eastern British Columbia.

The numbers observed in 1998 are comparable to previous studies on the Table River although sampling techniques are not necessarily comparable, In 1995 thirteen Arctic grayling were captured in the mainstem after sampling 15,198 square meters of habitat (8.5 HA^{-1} (Zemlak and Langston 1998 closed and open electrofishing sites). In 1996 only 65 fry were captured after sampling 22 open sites covering several kilometres of shoreline habitat in the Table River mainstem (distribution study, no area measurement taken). In 1997 at total of 114 Arctic grayling fry were captured from 2,245 lineal or 7,660 square meters of habitat.(51 km^{-1} or 148 HA^{-1} from habitat similar to the 1998 shoreline sites, but without stopnets).

The flow regime of the river may dramatically affect fry survival rates. Severe spring floods regularly can result in the loss of a year class (Tack 1974, Stuart and Chislett 1979). But in 1998, the Table River experienced a low spring run-off, which should have resulted in a lower mortality rate (more fry were captured in 1998 compared to 1995 and 1996; Mathias et al 1998). However, this lower early mortality rate may have been offset by high mortalities through stranding as summer water levels were very low. Arctic grayling fry concentrate in very shallow (<10 cm) stream margin areas (Blackman 2002 in prep) and numerous authors (deBruyn and McCart 1974, Peterson 1968, McCart 1972) have reported that mortalities through stranding can be very high. The severity of the problem is illustrated by the fact that on the Table and Anzac Rivers, it was not unusual to capture 25 to 200 Arctic grayling fry from small isolated pools along the stream margin (per obs). This number of fry would be equal to the mainstem production from several kilometres of stream (at 34 to 80 fry per kilometre). The low numbers of fry suggests that recruitment may be limiting the populations in these systems. Although fall electrofishing index sites will provide us with an index of changes in fry numbers, it will not provide answers to why or at what stage the problems are occurring.

Age 0+ and 1+ Habitat Utilisation

It was not anticipated that substantial numbers of Arctic grayling would be captured in the Parsnip River because of the high turbidity in that system and because none were captured during limited beach seine surveys conducted there in 1997. The Parsnip River may be more attractive to Arctic grayling because of the slightly warmer water temperatures. Predator avoidance, due to reduced visibility because of the slit load could be a factor, but this should be offset by an anticipated reduction in growth and food availability (Scannel, 1988).

Very few age 1+ Arctic grayling have been observed in either the Table of Anzac Rivers despite abundant habitat which appears to be suitable and limited competition from other species. Beach seine surveys in 1996 captured six 1+ Arctic grayling from the Table river after sampling over 30,000 square meters of habitat (Mathias et al 1998). Extensive electrofishing surveys conducted from1994 to1997 also failed to find any substantial utilisation by this age class in the Table and Anzac Rivers (Mathias et al 1998, Langston 1998, Zemlak and Langston 1998, Langston 1998). Underwater surveys conducted by the authors, during the same period found only a small number (<10), and these fish were all in shallow slow moving glide habitat in the lowest reaches and were not associated with any sort of cover.

The habitat utilisation work was conducted to give a gross indication of habitat preference for areas that could be sampled by beach seine (no areas with woody debris were sampled). No attempt was made to determine the specific micro habitat that an individual fish was utilising, but rather the number of fish captured from relatively homogeneous habitats was measured. Certain assumptions were also made, for instance mid channel depths, velocities and substrate were not evaluated for young of the year Arctic grayling because we assumed, based on other studies conducted in this area (Blackman 2002 in prep) and references from the literature (Armstrong 1986) that young of the year fry do not utilise this area. The intent of the estimates was to give generalised preferences.

Age 0+ Arctic grayling fry showed a strong preference for sites where water depth was less than 0.06 m. and velocities were less than 0.03 ms^{-1} one meter from shore. This preference for low velocity shallow habitat is consistent with the finding of other authors (Stewart et al 1982, Nelson 1954 Stuart 1979) but most authors suggest the fry move to deeper higher velocity areas as they grow. The young of the year Arctic grayling fry in the Table and Anzac rivers tend to remain in shallow water (<10cm) throughout the summer (Blackman 2002 in prep).

Age 1+ Arctic grayling preferred for low velocity (<0.20 ms^{-1}) sites with a depth between 0.40 and 1.0 m. The shallow low velocity glides in the Parsnip River may be the primary rearing area for this age class of Arctic grayling, not only from the Parsnip River but for fish from the Table and Anzac rivers as well. Analysis of the genetic data collected and the recapture of PIT tagged 1+ Arctic grayling from the Parsnip River should help verify this assumption.

The use of different systems by different life history stages is unusual but not unheard of. Numerous authors (Benock 1973, Tack 1973, 74, 75) have noted the spatial segregation of different ages classes of Arctic grayling within a system and Stein et al (1973) noted in the Mackenzie River System two or more systems may be utilised for different life history phases.

Adult Abundance Estimates

The objective of this segment of the program was to establish index sites for adult counts and to evaluate the validity of using mark-recapture methodologies for estimating Arctic grayling populations. The authors previously observed , that there may have been a change in the distribution of the marked Arctic grayling between tagging and underwater counts and that fish may have moved out of the study area during previous surveys. One site was established in each accessible reach of the streams, to ensure changes in distribution would not dramatically affect the total count. Two sites were established in the upper reach in the Anzac River because of the high percentage of the fish that are normally observed there in late summer

Underwater visibility ranged from 3.5 to 12 m with an average of 6 m during the counts. Arctic grayling in these rivers tend not to hide in debris or undercut banks but are concentrated in pools or deep glides (Zemlak and Langston 1998, Mathias et al 1998 Blackman 2002 in prep) and are therefore easily counted. Conversely, if the swimmer is on the wrong side of the fish, the large dorsal fin often makes it difficult to see floy tags. It is difficult to believe that under the water conditions encountered during the swim, only 50% of the fish would be counted as the results suggest. It is far more probable that either tags were missed or the tagged fish moved out of the area. It is also possible that both tagged and untagged fish were moving, but this type of movement pattern is not supported by radio telemetry data collected in these watersheds (Blackman 2001) and there was no indication that untagged Arctic grayling were moving.

Only 56% of the Arctic grayling tagged in the Table River were observed during the underwater count, but 18% of these fish had moved out of the 2 km tagging area. It is not known whether the remaining tagged fish were not seen, had moved further than the limits of the swim (4km) or if tags were missed. During the surveys on the Anzac River 76% of the tagged fish were observed, but 17% had moved out of the tagging area. Similar movements of marked

Arctic grayling have been reported from a number of Alaskan studies (Tack 1974, Ridder 1983, Clark 1989, Ridder 1989). The movement of the marked fish out of the area would result in a positive bias to population estimates.

The upper two sections surveyed on the Anzac River are located in a bed rock canyon and nearly all of the fish observed were in deep bedrock pools. There was no movement of tagged Arctic grayling in the upper section (km 47-45); but in the other canyon section (km 42-39), over 40% of the tagged Arctic grayling that were observed had moved downstream out of the tagging area. These fish had moved into a deep bedrock pool just downstream from the marking area but still within the area where the counts were conducted. In both of these sections the underwater counts are very close to the mark recapture estimates, because the tagged fish either did not move or did not move out of the swim area. It is surmised that this was because many fish that were inclined to move, stopped at the next deep pool usually downstream from where they had been tagged.

This was not the case in Reach three of the Anzac River, and probably in reaches 2 and 3 of the Table River. In Reach three of the Anzac River on the replicate swims 55% and 43% of the marks were observed and 19 and 23 % had moved out of the marking area. After the second swim an additional six tagged Arctic grayling were observed in the first deep pool downstream from the swim section. Similar results were obtained in Reaches 2 and 3 of the Table River. On replicate swims 49, 43, 64 and 61 % of the tagged Arctic grayling were observed but 35, 45,12 and 12 percent of the tags observed were outside the tagging area. It is not know if tags were missed or tagged fish moved completely out of the study area but it is relatively certain that the mark recapture estimates are resulting in high population estimates. In all the swims, fewer marked fish were observed on the second swim (except in reach three of the Anzac River), and when the second swim was not conducted on the same day, the decline in the number of marked Arctic grayling observed was greater. The number of marked bull trout and rainbow trout observed on the second swim, followed a similar pattern.

The method of using expanded counts to estimate the number of Arctic grayling may also lead to errors. In Reach three of the Anzac River three counts were conducted. Two swimmers conducted the first two counts; the visibility was five meters and the wetted width was 30 meters. The standard method for expansion would be to increase the count by 30/(2x5)x2. This would increase the count above the estimates obtained from the mark recapture methodology. An explanation for the difference is the nature of the stream in this area. The pools, where most of the Arctic grayling were observed, are narrower than the average wetted width and two swimmers can effectively count all the fish. The riffle areas, which are not utilised by adult Arctic grayling in these systems tend to have greater wetted widths. A third count was conducted using three swimmers and no expansion was necessary. On this swim 113 Arctic grayling were counted, the final mark recapture estimate for this section of river was 127 Arctic grayling with a standard error of 4.9.

The problem of tagged fish moving out of the survey area does not appear to exist with rainbow trout, where virtually no movement of tagged fish was observed. However because of the propensity of rainbow trout to hide in woody debris in these systems the percentage of tagged

fish observed was low at 34%. This may have been a result of conducting the counts too soon after the fish had been tagged and the rainbow trout were still hiding in debris jams. Most underwater count were conducted on the same day, or the day after tagging was completed (Appendix II). Predation of smaller marked rainbow trout by bull trout could also be a factor. The numbers of bull trout tagged (37), observed (18) and which were observed to have moved (4) were too low to give any information on movements. The highly migratory nature of this species particularly in late summer, just prior to spawning, would make mark recapture estimates very suspect. In late August bull trout may be "staging" in preparation for spawning, which can lead to extremely clumped distribution patterns. This was evident as nearly 40% of all the bull trout observed after surveying 30 km of river, were located in one pool at km 34 of the Table River (Appendix II). It would be very difficult to estimate the number of bull trout in these systems.

The estimates of 32 and 94 Arctic grayling per kilometre of stream in the two index sites of Reach 4 of the Anzac River are considered quite accurate. The tagged Arctic grayling did not move out of the swim area and these numbers are very close to the actual counts. However, in Reach 3 of the Anzac River, and Reaches 2 and 3 of the Table River the mark recapture the estimates are nearly double the counts. The estimates in these sections are positively biased (movement of tagged fish) and the counts are negatively biased (possible missed fish or fish displaced because of tagging) so the true number of fish in these areas was between the two estimates. The counts are probably very close to the actual number of Arctic grayling present during the swim because of the good underwater visibility during the surveys, and in the two sections of river where the tagged Arctic grayling did not leave over 80% of the tagged fish were observed. In Reach one of the Table River no estimates were made because no tagged fish were observed.

Surveys conducted in 1995 on the Table River (Zemlak and Langston 1998) counted slightly lower numbers (max 107-115) of Arctic grayling in reach three, but much higher numbers in reach one (19-33) than the 1998 surveys. The 1995 surveys extended upstream 0.5 and 0.9 km further and in 1995 water levels were slightly higher, which appears to affect the distribution of the Arctic grayling within the system (pers obs).

In future surveys, in order to reduce the problem of tagged fish moving, the length of the swims could be increased to 6 km. This extension of the swim would presumably locate more of the tagged fish that moved out of the tagging areas. However, in order to obtain statistically valid data a minimum of 20% of the estimated population should be marked. This would become more difficult to achieve when marking only one third of the area. A simpler solution would be not to mark any fish and conduct a minimum of three counts in each area. If these counts were conduced with a suitable number of swimmers (to avoid having to expand the counts) and under water conditions with a visibility of 4.5m or greater, the counts would provide Arctic grayling abundance estimates with minimal effort which could be replicated to provide relative abundance estimates.

Comparison of Ageing Structures

We have found that the method of ageing Arctic grayling through the use of scale samples is much less invasive than the use of fin rays or otoliths and it is much more economical. The collection of scale samples allows the use of scale backcalculation methods to determine growth rates of different age classes and for different years. However, any fish collected larger than 330 mm F.L. or older than five years old should be not be aged by scales as this method does underestimate the ages of older fish. This size will probably vary from system to system and the accuracy of age estimates will probably vary with individual scale readers.

Age Class Distribution of Arctic grayling.

The Arctic grayling populations which summer in the Table, Anzac and Parsnip Rivers are quite different with respect to age class distributions. The Arctic grayling population of the Anzac River is made up almost entirely of mature individuals and has a higher percentage of large individuals than the Table River population (Fig 13) and generally, the fish are also larger at age (Table 7). The Table River has a mixture of mature and immature fish. The Parsnip River, which has not been sampled sufficiently, appears to be dominated by the younger age classes and may be a rearing area for immature fish from all three systems. Radio telemetry studies (Blackman 2001) found that adult grayling, captured in late summer from the Anzac River spawned in all three systems.

This segregation of age classes is fairly common in Arctic grayling populations (Armstrong 1986, Reed 1964) and the use of different systems for different life history stages has also been reported (Stein et al 1973)

Pit tag Retention and Juvenile Growth Rates

Eight Arctic grayling juveniles (1+) that had been pit tagged in July were recaptured in September, but four had missing PIT tags. Tag loss could be reduced by using tissue glue to close the insertion hole. The recaptured age 1+ Arctic grayling grew an average of 10 mm and 3.20 g. The average growth rate of all age 1+ Arctic grayling captured from the Parsnip River was 11.2 mm and 3.13 g, which was not statistically different ($P<0.05$) than the tagged fish indicating that the tagging did not affect growth rates.

The 0+ Arctic grayling captured from the Parsnip River grew an average of 27.6 mm and 2.74 g from July to September. The average size of the fry in September was 75.3 mm and 3.85 g slightly larger ($P<0.05$) than the fry captured from the Table River (72.3mm and 3.48g) during the same time period. Both these groups were larger ($P<0.05$) than samples collected in previous years (65.0mm in 1995 ,48.6mm in 1996 and 53.4 in 1997) from the Table River (data on file). This larger size is probably because of the longer growing season in 1998 or higher summer water temperatures. The Parsnip River warms up earlier in the spring than the Table River (Table 1) and therefore Arctic grayling may spawn and hatch earlier. The Parsnip is also slightly warmer than the Table River throughout the summer. In other areas fry are reported to exceed

100 mm by freeze up (Delaney et al 1980) but 70 to 80 mm appears to be the norm. The 1996 and 1997 growth rates are is quite small in comparison with reports from Alaska (78mm Reed 1964),and the North West Territories (85mm Trip and McCart 1974).

Management Implications and Research Needs.

A combination of overfishing, introductions of competing species, and habitat degradation has resulted in the decline of many Arctic grayling stocks throughout their range. Common management prescriptions are reduced harvest, size limits and in some areas stocking. In many instances these measures have been ineffective at stopping the decline of local stocks (Vincent 1963). A more holistic approach is needed, with a better understanding of factors that can impact this species, and protection from impacts on key habitats.

The identification and protection of Arctic grayling spawning and early rearing areas is of prime importance, but this can be difficult, due to the migratory nature of this species and it's propensity to spawn during the spring high flow periods. Radio telemetry is an effective method to find spawning areas but can be very expensive, particularly if the fish are spawning, rearing and summering in different systems. The use of fry distribution surveys to locate spawning areas holds some promise as a cost effective method to locate spawning areas, but timing of the surveys, weather conditions and identification of the newly hatched fry is critical. Information should also be gathered to determine fidelity to spawning areas and if spawner distribution is affected by stream flow fluctuations.

Stream flow is critical for the survival of Arctic grayling during the first season. A common theme throughout the literature is that high flows and silt loads impact incubation. High stream flows can displace and cause high mortalities in newly hatch fry and late summer low flows can result in high losses due to stranding (Vincent 1963, Armstrong 1986, Trip and McCart 1974). Arctic grayling tend to spawn in shallow water so rapidly falling water levels just after spawning could potentially result in high egg mortalities, but this situation has not been documented in the literature. These impacts of changing hydrology are difficult to conclusively document and are more difficult to prevent. Logging in watersheds that support Arctic grayling may make these problems more severe by increasing silt loads and affecting the hydrological regime (Slaney et al 1977). More information is needed on the impacts of logging on the hydrological regime and subsequent impacts on Arctic grayling populations. Consideration should be given to the evaluation of controlled flow sidechannels to provide spawning and early rearing habitat, which could serve as a buffer against changing hydrological regimes. Projects that remove fry from isolated pools along the stream margins and return them to the main river (fry salvage) could be a significant benefit to depressed stocks, particularly in low flow years.

In many systems, age 1+ Arctic grayling rear in the lower reaches (Armstrong 1986, Reed 1964, Tack 1980). This age class moves out of the Table and Anzac rivers to rear in the Parsnip River which suggests they may require a specific type of habitat that is not available in smaller systems. Arctic grayling populations have disappeared from all rivers that flow into Williston Reservoir that are smaller than the Anzac River. This suggests that the reservoir may no longer provide suitable rearing habitat for this age class. A better understanding of the habitat

requirements of this age class will be necessary prior to any enhancement or restoration work being undertaken.

The establishment of index sites to monitor long term population trends in response to potential impacts or management prescriptions should be established in several systems. Careful planning will be necessary to ensure the effectiveness of any monitoring program. Changes in populations could be easily masked because of the migratory nature of this species, the tendency for age classes to be segregated and for distributions in a system to change with flow regimes.

Work is underway (Stamford 2001) to find genetic markers so that specific stocks can be identified. This is particularly important in areas where stocks may overlap or utilise more than one system. This will also be a valuable tool to determine specific migratory patterns and life history strategies, which appear to be extremely variable.

Single system management of Arctic grayling may not be effective because populations can utilise different systems for different life history stages and different "stocks" may utilise the same areas. A broader based, long term approach, which takes into account differing life history strategies and utilisation of different habitats and systems will be necessary to ensure the survival of individual "stocks".

ACKNOWLEDGEMENTS

Co-funding for this years' Table and Anzac Rivers Arctic grayling study was provided by Forest Renewal British Columbia through the Watershed Restoration Program (File Plan #OPA98102), and the Peace/Williston Fish and Wildlife Compensation Program. Several individuals from the British Columbia Conservation Foundation, Prince George, assisted in collecting the field data for this study. These people include: Steve Biancolin, Marco Giroux and Peter Hall. Their hard work and determination was much appreciated. Arne Langston and Randy Zemlak, PWFWCP staff, also assisted in the field work and provided advise in the production of this report. Bob Westcott and Nick Baccante provided much appreciated advise in the production of this report.

REFERENCES

Anonymous. 1978. Report on environmental studies for the McGregor River diversion project Vol. 1-4 Prepared by Reid, Crowther and Partners Limited for B.C. Hydro and Power Authority.

Anonymous. 1995. Tracking list for vertebrate animals, vascular plants and plant communities. British Columbia Conservation Data Centre, Wildlife Branch, Ministry of Environment, Lands and Parks, Victoria, B.C.

Armstrong, R.H. 1986. A review of Arctic grayling studies in Alaska 1952-1982. Biol. Pap. Univ. Alaska No. 23.

Barrett, D.T., and T.G. Halsey. 1985. Fisheries resources and fisheries potential of Williston Reservoir and its tributary streams. Volume I. Prov .B.C. Fish. Tech. Circ. No. 68:40 p

Baxter J.S. 1997. Summer Daytime microhabitat use and preference of bull trout fry and juveniles in the Chowdale River, British Columbia. B.C. Environment Fisheries Management Report No. 107: 36pp.

Blackman, B.G., D. Jesson, D. Ableson, and T. Down. 1990. Williston Lake Fisheries Compensation Program management plan. Peace/Williston Fish and Wildlife Compensation Program, Rpt. No. 58. 38p

Blackman B.G. and K. Newsholme 1993. Williston Reservoir 1989 creel report Peace/Williston Fish and Wildlife Compensation Program, unpubl report 31p.

Blackman, B.G. 1992 Fisheries Resources of Williston Reservoir twenty years after impoundment. Prov of B.C. and B.C. Hydro Environmental Resources unpubl Man Rep. 35p + appendices.

Blackman, B.G. and A.R. Langston. 1992. Fisheries Resources and enhancement potentials of selected tributaries of the Williston Reservoir Volume I unpubl man rep 49 p + appendices.

Blackman, B.G. 1995. Table River watershed fish habitat assessment. Application for funding to Forest Renewal B.C., Ministry of Environment, Lands and Parks, Prince George, B.C. 7 pp.

Blackman, B.G. 2001. Radio telemetry studies of Arctic grayling migrations to overwintering, spawning and summer feeding areas in the Parsnip River watershed. Peace/Williston Fish and Wildlife Compensation Program, Report in prep.

Blackman, B.G. 2001. A strategic plan for the conservation and restoration of Arctic grayling in the Williston Reservoir Watershed. Peace/Williston Fish and Wildlife Compensation Program, Report in prep.

Blackman, B.G. (2002 in prep) Arctic grayling habitat use in the Table and Anzac Rivers. Peace/Williston Fish and Wildlife Compensation Program, Report in prep.

Bozek, M.A., and FJ. Rahel. 1992. Generality of microhabitat suitability models of young Colorado River cutthroat trout (Onchorhyncus clarki pleuriticus) across site and among years in Wyoming streams. Can Journal of Fish and Aquat Sc. 49:552-564

Bruce, P.G., and PJ. Starr. 1985. Fisheries resources and fisheries potential of Williston Reservoir and its tributaries streams. Vol. II. Fisheries resources potential of Williston Lake tributaries - a preliminary overview. Prov. B.C. Fish. Tech. Circ. No. 69: 100 pp.

Cheslak, E.F., and J.C. Garcia. 1988. An evaluation of the effects of various smoothing and curve fitting techniques on the accuracy of suitability functions. U.S. Fish and Wildlife Service Biological Report 88:259-286

Clark, R.A. 1989. Stock assessment of Arctic grayling in the Salcha and Chatanka Rivers. Alaska Department of Fish and Game Fishery Data Series, Juneau Alaska,

Koning, C.W., K.I. Ashley, P.A. Slaney, R.W. Land, and P.W. Davidson. 1995. Development of a premier northern river fishery: Mesilinka River pre-fertilisation progress 1992-1993. Pea-e/Williston Fish and Wildlife Compensation Program, Report No. 82: 37 pp.

Langston, A.R. 1998. A reconnaissance survey of the Table River: 1995 status report. Peace/Williston Fish and Wildlife Compensation Program, Report No. 178: 31 pp.

Paul, A.J., C.W. Koning, K.I. Ashley, P.A. Ashley, P.W. Davidson, and R.W. Land. 1996. Development of a premier river fishery: Mesilinka River, the first year of fertilisation (1994). Peace/Williston Fish and Wildlife Compensation Program, Report No: 85. 48 pp.

Prentice, E.F., T.A. Flagg, and C.S. McCutcheon. 1990. Electronic tags: Feasibility of using implantable passive integrated transponder (PIT) tags in salmonids. Am. Fish. Soc. Sym. 7: 317-322.

Prentice, E.F., TA Flagg and C.S. McCutcheon, D.F. Brastow, and D.C. Cross 1990a. Equipment, methods, and an automated data entry station for PIT tagging. American Fisheries Society Symposium 7: 335-340

Langston, A.R. and R.J. Zemlak. 1997. Summary of the 1994 fish trapping operations on Suschona and Sylvester Creeks. Williston Fish and Wildlife Compensation Program, Report No. 76:132pp plus appendices

Langston, A.R. 1998. A reconnaissance survey of the Table River: 1995 status report. Peace Williston Fish and Wildlife Compensation Program, Report No. 178: 32pp plus appendices.

Langston, A.R. 1998. Evaluation of the 1992 and 1993 Arctic grayling *(Thymallus arcticus)* transplants to Little Calais Lake and current fish population status. Peace Williston Fish and Wildlife Compensation Program, Report No. 1998: 11p.

Larkin, G.A., G. Willison, K.I. Ashley, P.A. Slaney, R.W. Land, and S. Bioncolin. Development of a premier northern river fishery: Mesilinka River, the fourth year of fertilization (1997). B.C. Min of Env. Lands and Parks. Fish Report No. RD70 27p plus appendices

McLean, A.R. 1992. A reconnaissance survey of Little Calais Lake. Peace/Williston Fish and Wildlife Compensation Program, Report No. 112: 32 pp.

Nelson, P.H. 1954. Life history and management of the American grayling (Thymallus signifer tricolor) in Montana. J. Wildl. Manage. 18: 324-342.

Northcote, T.G. 1993. A review of management and enhancement options for the Arctic grayling (Thymallus arcticus) with special reference to the Williston Reservoir watershed in British Columbia. Prov. B.C., Fish. Br., Fish. Manage. Rep. No. 101: 69 pp.

Reed, R.J. 1964. Life history and migration patterns of Arctic grayling T. arcticus in the Tanna River Drainage of Alaska. Alaska Dept f Fish and Game Research Report: 30p

Ridder, W.P. 1983. A study of a typical spring fed stream of interior Alaska. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, annual Report of Progress 1982-1983. Project F-(-15, 24 (G-III): 54 pp.

Ridder W.P. 1989. Age length sex and abundance of Arctic grayling in the Goodpaster River 1956 through 1988. Fishery Data Series No. 94 Alaska Dept of Fish and Game.

Scannel, P.O. 1988. Effects of elevated sediments levels from placer mining on survival and behaviour of immature Arctic grayling. Alaska Coop. Fish Unit, Contribution No. 27, Fairbanks Ak. MSc. Thesis, Univ. Alaska Fairbanks Ak. 93p.

Slaney, P.A, T.G. Halsey and H.A. Smith 1977. Some effects of forest harvesting practices on salmonid rearing habitat of two streams in the Central Interior of British Columbia. Fish Mgmt Report No. 71. Fish and Wildl. Br. Victoria B.C. 26p.

Slaney P.A., T.G. Halsey and A.F. Tautz 1977. Effects of forest harvesting on spawning habitat of stream salmonids in the Centennial Creek Watershed, British Columbia.. Fish Mgnt Report No. 73 Fish and Wildl Br. Victoria B.C. 39p.

Slaney, P.A, and A.D. Martin. 1987. Accuracy of underwater census of trout populations in a large stream in British Columbia. North Arner. J. Fish. Man. 7: 117-122.

Stamford, M.D. 2001. Phylogeography and conservation genetics of Arctic grayling (Thymallus arcticus) in North America. M.Sc, thesis, University of British Columbia, Vancouver, B.C.

Stein , .N., C.S. Jessop, T.R Porter and K.T.J. Chang-Kue. 1973. An evaluation of the fish resources of the Mackenzie River valley as related to pipeline development. Oil Development Report No. 73-1, Eviron. Social Comm. North. Pipelines, Task Force on North Volume 1. 122.p

Stuart, K.M. and G.R. Chislett. 1979. Aspects of the life history of Arctic grayling in the Sukunka drainage. Prov. B.C., Fish. Br., Prince George, Internal rep. 111 pp.

Tack, S.L. 1974. Distribution, abundance and natural history of the Arctic grayling in the Tanana River drainage. Alaska Dept. Fish and Game, Ann. Rep. Of Prog. 1972-1973, Proj.F-9-5, 14(R-I), 52 pp.

Tripp, D.B. and PJ. McCart. 1974. Life histories of grayling (Thymallus arcticus) and longnose suckers (Catastomus catastomus) in the Donnelly River system, Northwest Territories. Arctic Gas Biol. Rept. Ser. Volume 20, Chapter 1 91p.

Van Whye, G. 1962. Inventory and cataloguing of sport fish and sport fish waters of the Cappoe River and Prince William Sound drainages. Alaska Dept. Fish and Game, Ann. Rep. Of Prog. 1961-1962, Proj. F-5-R-3, 3(II-A):227-243.

Vincent, R.E. 1963. Biogeographical and ecological factors contributing to the decline of Arctic grayling Thymus Arcticus in Michigan and Montana. University of Michigan Ph.D. Thesis 1962, 169p.

Vincent, E.R. 1971. River electrofishing and fish population estimates. Prog. Fish. Cult. 33(3): 163-169.

Wydoski, R.S. 1977. Relation of hooking mortality and sublethal hooking stress to quality fishery management, pp. 43-87 in R.A. Bernhart and T.D. Roelofs (eds.) Proceedings of a national sport fishing symposium: catch and release fishing. Humboldt University, Arcata, California.

Zemlak, R.J. and A.R. Langston. 1990. Fish species presence and abundance of the Table River, 1995. Peace Williston Fish and Wildlife Compensation Program, Report No. 173. 28pp plus appendices.

APPENDIX I

Young-Of-The-Year Fry Distribution Data: Table and Anzac Rivers

Table River Early Fry Distribution

Date	Site	KM	utm			Sample	# fry Total	# fry 0-50	50-100	100-150	150-200	200-250	250-300	300-350	350-400
6/16/98	T1	1	10	545686	6062448	e	600	0	100	250	250				
6/16/98	T2	3		546247	6062790	f	47	0	0	5	5	0	18	19	
6/16/98	T3	4.2		547395	6063551		13	6	1	0	0	6	0		
6/16/98	T4	6.3		548265	6063891		7	0	7						
6/16/98	T5	7.4		549104	6064430		31	2	2	26	0	1	0		
6/16/98	T6	8.3		549757	6064692		2	0	2	0					
6/16/98	T7	10.7		550731	6065443		35	0	3	20	0	12			
6/16/98	T8	11.7		551492	6065632		13	1	4	0	0	8			
6/16/98	T9	12.3		551987	6065775		8	8	0	0	0	0			
6/16/98	T10	13.5		552750	6066290	767	11	0	11	0					
6/17/98	T11	15.5		553876	6066491		0	0	0	0	0				
6/17/98	T12	16.5		554627	6067102		1	1	0	0	0	0	0		
6/17/98	T12A	16.7		554950	6067263		0	0	0	0	0				
6/17/98	T13	18.5		555975	6067056		0	0	0	0					
6/17/98	T14	20.5		557210	6067814		8	0	1	0	0	0	0	7	
6/17/98	T15	21.3		557390	6067802	g	11	0	11						
6/17/98	T16	22.3		558095	606702		0	0	0						
6/17/98	T17	23		558515	6067962		2	0	1	1	0	0			
6/17/98	T18	23.7		559237	6068662	h	0	0	0	0	0	0		-	
6/17/98	T19	25.4		559656	6070016		0	0	0						
6/17/98	T20	25.5		559656	6070016		0	0	0	0	0				
6/17/98	T21						0								
6/17/98	T22	24.7		559396	6069101		0	0	0	0					
6/17/98	T23	26.4		559840	6070208		0	0	0	0					
6/17/98	T24	27.5		560819	6070566		0	0	0	0	0				
6/17/98	T25	23.8		561083	6070535		0	0	0						
6/17/98	T26	28.2		561563	6070973		0	0	0	0	0				
6/17/98	T27	29		561859	6070989	i	2	2	0	0	0	0			
6/17/98	T28	29.5		562188	6071286		0	0	0	0	0	0			
6/17/98	T29	30		562476	6071694	l	0	0	0	0	0				
6/17/98	T30	30.6		562800	6071808		0	0	0	0	0				
TotalFry Observed							791	20	143	302	255	27	18	26	0
Number of 50 m sites surveyed							124	30	30	25	20	12	5	2	0

Anzac River Early Fry Distribution

Date	Site	KM	utm			Sample	# fry Total	# fry 0-50	50-100	100-150	150-200	200-250	250-300	300-350	350-400	400-450	Comments
6/18/98	1	1	10	530079	6072946	k	2	0	0	0	0	0	2	0			both fry 14 mm
6/18/98	2		10	530965	6072183		0	0	0	0	0	0					
6/18/98	3	3	10	531250	6071827	l	15	0	11	4							all 15 mm
6/18/98	3a		10	531399	6072024		2	0	1	1							all <15mm
6/18/98	4		10	532017	6076042		1	0	0	0	0	0	0	0	1		25 mm
6/18/98	5		10	533528	6077035		0	0	0	0	0						
6/18/98	6		10	536622	6079012		0	0	0	0	0	0	0				
6/18/98	7	15	10	537055	6078923	m	18	14	0	4	0						<15mm
6/18/98	8	20	10	540267	6079791	0	5	4	1	0	0						2>20,3<15
6/18/98	9		10	541263	6080979		0	0	0								
6/18/98	10		10	543493	6082503		0	0	0	0	0	0	0	0			
6/18/98	11		10	543493	6083799		0	0	0	0	0						
					Total		43										

Table River Fry distribution

Date	Site	KM	utm		Sample	# fry	# fry																	
			Easting	Northing		Total	0-50	50	100	150	200	250	300	350	400	450	500	550	600	650	700	750	800	850	900
98/06/30	T 1.1	1	545563	6062321	1,2	80	0	0	30	50														
98/06/30	T1.2	1.7	545836	6062440	3	152	100	52																
98/06/30	T1.3	2.4	545961	6062502	4	327	1	0	6	250	0	0	20	50										
98/06/30	T1.4	3	546093	6062745	5	182	0	12	150															
98/06/30	T2.1	3.2	546304	6062720	6	92	30	0	0	12	0	50												
98/06/30	T2.2	4.2	547326	6063342	7	344	25	25	50	1	3	40	200											
98/06/30	T3.1	5	547791	6063516		0	0	0	0	0	0													
98/06/30	T3.2	5.3	547546	6063555	8	200	0	0	0	0	0	200												
98/06/30	T3.3	5.6	547791	6063516		2	0	2	0															
98/06/30	T3.4	5.7	548364	6063590		6	0	0	0	6														
98/06/30	T3.5	5.9	548069	6063572		3	0	0	0	0	3													
98/06/30	T3.6	6.J	548364	6063590	9	260	0	10	250															
98/06/30	T4.0	6.3	548346	6063572		7	0	0	0	0	0	0	0	7										
98/06/30	T 4.2	6.6	548577	6063886		5	5	0	0	0														
98/06/30	T4.3 T5	7.3	549036	6064120	10	2	0	0	0	0	0	2	0											
98/06/30	T5.1	7.9	549320	6064369	11	30	0	0	0	30														
98/06/30	T5.2	8.2	549654	6064180		10	0	0	0	0	0	10												
98/06/30	T6.2	9.3	550303	6064454	12	45	0	45	0	0														
98/06/30	T6.3	9.7	550405	6064860	13	220	220	0	0	0	0	0												
98/06/30	T6.4	10.5	550630	6065534	14	17	12	5	0	0	0													
98/06/30	T7.1	10.7	550787	6065402	15	20	0	20	0															
98/07/01	T7.2	10.9	551081	6065362	16,17,18	232	50	0	7	0	65	0	0	20	0	30	0	60	0	0	0			
98/07/01	T8	11.2	551321	6065573	19	28	0	2	1	0	5	10	5	0	5	0	0	0	0	0	0			
98/07/01	T8.1	11.5	551378	6065376		10	0	0	10	0	0	0	0	0	0	0	0	0	0	0				
98/07/01	T8.2	12	551553	6065730	20,21	0	0	0																
98/07/01	T9.0	12.3	551956	6065746	22,23	45	20	0	0	0	0	0	25											
98/07/01	T9.1	12.5	552289	6066263	24	322	0	2	0	0	0	200	0	100	0	20								
98/07/01	T9.15	12.7	552491	6066438		394	200	0	0	2	0	0	25	0	12	150	0	5						
98/07/01	T9.2	12.7	552146	6065926	25,26,27	206	40	0	6	100	0	0	0	0	0	30	30	0	0	0	0			
98/07/01	T10	13.5	552795	6066309		257	2	3	2	1	3	1	200	45	0									
98/07/01	T10.1	14.5	552505	6066093	28,29,30	282	0	0	0	0	0	12	25	25	20	200								
98/07/01	T11	15.4	552785	6066309	31	914	500	0	0	5	2	0	5	2	0	0	400	0						
98/07/01	T11.1	16.2	554367	6067036	32	20	0	0	20	0	0													
98/07/01	T12	16.5	554599	6067261	33	103	1	2	0	0	0	0	100											
98/07/01	T12.1	17	555031	6067338		1236	0	0	0	2	0	1	0	1	0	200	300	300	400	2	30			
98/07/01	T12.2	17.5	554810	6067231	34,35,36	65	0	0	0	0	20	0	20	0	25									
98/07/01	T13.1	18.5	555970	6067080		195	150	10	13	10	12													
98/07/02	T13.2	18.7	556102	6066963		1456	7	10	1000	20	0	0	0	4	10	200	0	0	0	0	0	0	200	5
98/07/02	T13.25	19	557067	6067619	37,37F,38	949	0	0	25	50	25	400	10	0	150	13	0	3	20	250	3	0	0	0
98/07/02	T13.3	19.4	556480	6067097	39	1204	350	50	10	3	1	10	200	10	5	3	6	2	5	2	3	10	4	30
98/07/02	T14	20.5	557216	6067803	40,41	1030	0	0	250	200	20	500	0	0	0	60	0							
98/07/02	T14.1	21	557541	6067819		295	100	120	0	0	60	0	0	5	0	0	10							
98/07/02	T14.2	21.4	557829	6067683		0	0	0	0	0	0													
98/07/03	T15	21.8	558182	6067476		417	0	5	200	75	0	0	40	0	10	12	35	40						
98/07/03	T15.1	22	558559	6067686		168	80	80	0	1	7													
98/07/03	T16	22.5	558441	6067990		96	1	10	35	30	20													
98/07/03	T16.1	22.7	558371	6068282		126	70	10	15	6	0	25												
98/07/03	T17	23	558885	6068178		65	0	0	0	0	9	0	0	4	0	0	0	0	21	0	1	30		
98/07/03	T17.05	23.4	558961	6068230		16	6	0	8	2	0	0	0	0	0	0								
98/07/03	T17.1	23.5	559038	6068358		117	14	10	0	0	1	10	10	2	36	34								
98/07/03	T18	23.7	559165	6068690		109	4	15	21	0	10	27	0	5	0	0	25	2						
98/07/02	T22	24.7	559407	6069187		106	12	2	0	0	2	0	5	0	0	6	25	0	0	30	7	0	12	2
98/07/02	T20	25.5	559673	6070030	44,445	896	0	2	12	2	40	40	70	150	120	80	70	20	20	10	90	0	10	200
98/07/02	T23	26.4	559957	6070198		162	0	100	7	24	3	0	0	9	6	0	0	7	6	0	0	0	0	
98/07/02	T23.5	26.6	560114	6070554		506	200	15	45	0	25	30	90	65	6	25	5							
98/07/02	T23.6	27	560582	6070425		167	17	25	20	25	15	20	25	20										
98/07/02	T23.7	27.5	560840	6070524		168	1	0	20	24	18	85	20											
98/07/02	T24	28	561345	6070647		94	18	0	2	30	6	8	3	3	1	6	0	5	8	4				
98/07/02	T24.5	28.4	561622	6070888		8	0	2	0	3	2	1												
98/07/02	T27	28.5	562056	6071036		47	5	20	0	0	12	10												
98/07/02	T27.1	29	561851	6071357		253	100	100	15	6	12	0	20											
98/07/02	T28	29.5	561938	6071577	45,46	340	3	20	50	125	30	20	80	12										
98/07/02	T28.1	29.7	562245	6071339		328	3	20	90	125	30	20	80											
98/07/02	T29	30	562521	6071789	47	39	5	12	2	20														
98/07/02	T29.1	30.4	562650	6071606		47	0	1	1	0	25	10	2	0	8									
98/07/02	T30	30.6	562823	6071903		67	50	2	10	5														
98/07/02	T31	31	562927	6071948		25	0	0	10	15														
98/07/02	T30.5	32.6	563578	6072516	42,43	53	4	18	0	0	10	6	0	12	2	0	0	1						
			Total # Fry		13241		2406	839	2353	1280	496	1748	1280	551	416	1069	906	445	480	298	94	40	226	237
			Total #50m sites		585		68	68	66	62	54	48	39	32	29	25	21	18	13	13	11	7	6	5

Anzac River Fry distribution

Date	Site	KM	utm	Easting	Northing	Sample No.	#fry 0	50	100	150	200	250	300	350	400	450	500	550	600	650	700	750	800	850	900	COMMENTS
98/07/08	0.00	0.0	10	529746	6072367		8	12	175	0	0															TEMP 14 C
98/07/08	1.00	0.7	10	529949	6072716		1	8	4	5	0	2	1	4	0	1	0	0	0							
98/07/08	1.10	1.4	10	530208	6072634	5,6,7,8	12	0	35	3	0	8	90	130	0	0	10	60								90,130 BC SAMPLES FRY ARE
98/07/08	1.20	1.8	10	530569	6072300	9	75	0	0	6																
98/07/08	2.00	2.1	10	530929	6072286		2	4	1																	
98/07/08	2.1A	2.3	10	530992	6072245		0	1	0	0	0	0	12	0												
98/07/08	2.1B	2A	10	530992	6072245		2	0	1	1	0	1														ALL FISH 22-26MM
98/07/08	3.0A	2.7	10	531333	6071956		0	0	2	0	0	0	0	0	2	0	3									
98/07/08	3.0B	2.7	10	531334	6071969	10	0	0	60																	14 MM
98/07/07	3.50	3.2	10	531437	6075532		0	0	0																	15 C @ 9:45
98/07/08	3.10	3.2	10	531685	6072135		8	1	0																	
98/07/08	3.20	3.8	10	531886	6072889		4																			22-30 MM
98/07/08	3.30	4.2	10	531862	6073000		11	16	2																	11@25-30,16@11-14,2@26MM
98/07/08	3.40	4.4	10	531881	6073240		0	0	0	0	0	0	0	0	0	0	0	0	1	5	1	4	0	6		
98/07/07	3.60	7.0	10	531385	6075596		1	0	0	2	0															2 OF THE FISH IN SIDECHANN
98/07/07	3.70	7.3	10	531548	6075789		1	0	0	0	0	0	2	8	0	0	0									8 IN BW
98/07/07	4.00	7.9	10	531973	6075977		60	0	0	0	0	0														FISH IN TAIL OF SC
98/07/07	4.10	8.2	10	532095	6076407		25	0	0	0	6	40	100													25 BC 100 TOP OF BAR~A
98/07/07	4.20	8.8	10	532465	6076663		38	8	0	0	2															
98/07/07	4.30	9.2	10	532585	6076952		8	0	0	0																MOUTH OF TRIB
98/07/07	4.40	9.5	10	532465	6076846		0	3	0	0	7	20	2	0	0											
98/07/07	5.00	10.3	10	533462	6077071		2	0	15	2	1	0	0	0	0	0	1	1								
98/07/07	5.20	11.0	10	534127	6077057	1	500	70	0	0	0	3	3	1	2	0	0	1	0							FRY 10-15 MM IN MUDDY BAC
98/07/07	5.30	11.4	10	534625	6077519		8	0	0	1	1	0														
98/07/07	5.40	11.6	10	534661	6077710		70	35	0																	ALL FISH IN BACKCHANNEL
98/07/07	5.40	11.6	10	534807	6077693	2	45	0	7																	MAIN. 1/2 FISH<15MM SAMPLE
98/07/07	6.00	12.0	10	534344	6077067		0	0	2	12	2	2	11	6												60%<15MM
98/07/07	6.10	12.3	10	534512	6078029		70	35	0																	ALL IN BC
98/07/07	6.20	12.5	10	534764	6077999		20	0	5	0	0	0	0	1												20 IN BW
98/07/07	10.00	12.5	10	534734	6077975		45	8	25	5	13	0														
98/07/07	10.10	12.8	10	535056	6077958		30	20	18	25	100	25														
98/07/07	6.40	13.0	10	534959	6078392		3	4	8																	ALL > 15MM
98/07/09	9.30	14.6	10	536668	6078472		0	0	700	0	40	10	15	0	9	10	1	0	0	7						
98/07/09	9.40	14.7	10	536952	6078402		0	0																		
98/07/09	9.50	15.3	10	537278	6078285		15	25	0	0	10	10	10	0	0	12	13	215	0	0	30	10				
98/07/09	9.60	15.5	10	537562	6078206	19	0	0	35	20	28															SAMPLE 2 @ 26 MM 1/2 FRY 1
98/07/09	9.70	16.2	10	537633	6078518	18	500																			50 M BAR BACKWATER A BOT
98/07/09	9.80	16.5	10	537802	6078558	17	0	70	37	0																SAMPLE 11-14 MM
98/07/09	12.00	16.6	10	538019	6078849	11,12	150	2	5	2	8	3	12	1	0	2	12									BC
98/07/09	9.90	16.7	10	537882	6078686		0	0	12																	
98/07/09	12.10	17.0	10	538502	6078758	13	34	20	5	0	0	0														FIRST28 @ 30MM REST 13 MI
98/07/09	12.20	17.5	10	538745	6078694		22	0	0	65	0	14	0	3	18	85	5	0	0	0	0	0	0	0	4	FRY 25&14 MM
98/07/09	12.30	18.2	10	538979	6079628	14,15	7	5	3	0	190	30														190@14MM
98/07/09	12.40	18.5	10	539189	6079360		0	50	27	15	100															BC FRY 14 MM
98/07/08	14.10	19.0	10	539403	6079783		0	15	20	0	3	0	0	0	7	3	0	2	0	7	0	3				OXBOW BY PICKERINGS
98/07/08	14.20	19.0	10	539642	6079785		0	0	0	0	0	0	0													OXBOW JUNCTION OF 3 INLE
98/07/09	12.50	19	10	539415	6079502.0		10	0	1	0	0	0	0	12	0	10	4	0								
98/07/08	14.00	19.5	10	540260	6079796		0	0	0	0	0	0	0	15	0	15	0	5	0	25	0	0	0	0	25	DOWNSTREAM FROM JUNCTI
98/07/09	13.00	19.5	10	540345	6079303	16	30	0	0	4																BC 20-25 MM JUST BELOW JU
98/07/08	14.40	19.8	10	540260	6079796	3	6	6	5	2	54	24	6	200	15	3	0	0	0	25	0	0				54 IN A 200 SC/A TWO SAMPL
98/07/08	14.30	20.0	10	539898	6079947		0	12	0	0	0	0	1	12	7	0										MAINSTEM DOWN TO JUNCTI
98/07/09	13.10	20.0	10	539892	6079960		110	8	2	1	48	10														70% 14MM 30%25MM
98/07/08	14.50	20.2	10	540442	6079925		0	2	15	30	7	32	8	0	0	33	0	1								START BOTTOM OF ISLAND
98/07/09	13.20	20.5	10	540085	6080398		34	14	0	3	8	20														
98/07/08	14.60	20.6	10	540813	6080204	4	200	75	30	50	12	0	0	0	5	10	10	10	10	10	10	15	5			200 IN BC
	Total No. Fry Observed					6556	2168	529	1257	274	638	254	273	393	63	184	59	295	11	80	41	32	5			
	Number of 50 m sites surveyed					423	55	53	52	42	38	33	24	22	19	18	17	14	10	8	7	7	4			

Table River Fry Identification 1998

Vial#	Species	Site	Location		UTM Easting	UTM Northing	Date Captured	Fork Length (mm)
A	2 RMWF	24	below hill 427				98/06/11	26mm 27mm
B	4 Suckers	24					98/06/11	4 Larvae
C	4 Suckers	24					98/06/11	10mm
D	1 RMWF	24					98/06/11	22mm
E	2 RMWF	1	1 km	10	545556	6062449	98/06/16	30mm 25mm
	3 A.G.							16mm, 15mm ?
F	2 RMWF	2	2 KM	10	544624	6062799	98/06/16	29mm, 27mm
f	**2 A.G.**	2	2 KM					**13mm, 15mm**
G	**2 A.G.**	**15**	**21 KM**	**10**	**557390**	**6067802**	**98/06/17**	**10mm, 10mm**
H	1 RMWF	18	24 KM mouth	10	559237	6068662	98/06/17	30mm
I	1 RMWF	29	30KM	10	562476	6071694	98/06/17	24mm
J	**2 A.G.**	**27**	**27KM, D.S.T.**	**10**	**561259**	**607989**	**98/06/17**	**Alevin & Fry, 11mm**
1	1 Sucker	T1	2	10	54627	6062366	98/06/30	
2	5 Suckers	T1	2	10	545627	6062366	98/06/30	15mm
	2 A.G.	T1	2	10	545627	6062366	98/06/30	25mm
3	5 Suckers	T1.2	2.4	10	545836	6062440	98/06/30	
	1 A.G.	T1.2	2.4	10	545836	6062440		
4	14 Suckers	T1.3	2.4	10	545837	6062599	98/06/30	
5	11 Suckers	T1.4	2.6	10	546033	6062745		
6	11 Suckers	T2.1	4.2	10	546304	6062729		
7	6 Suckers		4.2	10	547326	6063342		
8	12 Suckers	T3.7	5.3	10	547649	6063444		
9	14 Suckers	T3.8	5.7	10	548210	6063515		
10	**2 A.G.**	**T5**	**7.4**					**24mm**
11	8 Suckers	T5.1	7.9	10	549451	6064213		
12	4 Suckers	T6.2	9.3	10	551393	6064454		
13	5 Suckers	T6.3	9.5	10	550435	6064863		11mm
	2 A.G.		9.5	10	550435	6064863		20mm
14	6 Suckers	T6.4	9.7	10	550630	6065534		
15	4 Suckers	T7.1	10.7	10	550797	6065402		
16	4 Suckers	T7.2	10.9	10	551091	6065362	98/07/01	11-13mm
17	3 Suckers	T7.3	10.9	10	551182	6065475	98/07/01	12-14mm
18	5 Suckers	T7.4	10.9	10	551190	6065479	98/07/01	11-13mm
19	3 Suckers	T8.0	11.2	10	551421	6065573	98/07/01	14mm
	3 A.G.		11.2	10	551421	6065573	98/07/01	25mm
20	8 Suckers	T8.2	12	10	551553	6065739	98/07/01	
21	3 Suckers	T8.2	12	10	551539	6065730	98/07/01	
22	2 Suckers	T8.0	12.3	10	552137	6065927	98/07/01	12-13mm
23	4 Suckers	T8.0	12.3	10	552006	6065851	98/07/01	11-13mm
24	3 Suckers	T9.1	12.5	10	552377	6066348	98/07/01	Largest yet
25	6 Suckers	T9.2	12.7	10	552407	6065968	98/07/01	12-13mm
	1 A.G.		12.7	10	552407	6065968	98/07/01	23mm
26	6 Suckers	T9.2	12.7	10	552146	6065826	98/07/01	11-13mm
27	3 Suckers	T9.3	12.7	10	552525	6066092	98/07/01	12mm
28	5 Suckers	T10.1	14.5	10	553560	6066425	98/07/01	
29	2 Suckers	T10.1	14.5	10	553460	6066468	98/07/01	11-12mm
30	9 Suckers	T10.1	14.5	10	553678	6066471	98/07/01	11-13mm
31	8 Suckers	T11	15.4	10	553820	6066589	98/07/01	
32	4 Suckers	T11.1	16.2	10	554367	6067114	98/07/01	11-12mm
	1 A.G.		16.2	10	554367	6067114	98/07/01	20mm
33	6 Suckers	T12.0	16.6	10	554780	6067218	98/07/01	10-12mm
34	4 Suckers	T12.2	17.5	10	555934	6067402	98/07/01	11-12mm
	1 A.G.		17.5	10	555934	6067402	98/07/01	17mm
35	1 Sucker	T12.2	17.5	10	555793	6067483	98/07/01	11mm
36	4 Suckers	T12.2	17.5	10	556624	6067557	98/07/01	11-12mm
37.1	12 Suckers	T13.2	19.7	10	556119	6068958	98/07/02	12mm
37.2	12 Suckers		19.2				98/07/02	
37.3	5 Suckers		19.3				98/07/02	
37.4	3 Suckers		19.3				98/07/02	
38	7 Suckers	T13.2	19.7	10	556290	6067234	98/07/02	12-13mm
39	3 Suckers	T14.0	19.4	10	557190	6067942	98/07/02	14-15mm
	1 A.G.		19.4	10	557190	6067942	98/07/02	19mm
40	4 Suckers	T14.0	20.6	10	557366	6067901	98/07/02	12mm
41	5 Suckers	T13.3	20.5	10	556730	6067704	98/07/02	12mm
	1 A.G.		20.5	10	556730	6067704	98/07/02	24mm
42	**3 A.G.**	**T31.5**	**32.6**	**10**	**563578**	**6072516**	**98/07/02**	**>>20mm**
43	**8 A.G.**	**T31.5**	**32.6**	**10**	**563512**	**6072503**	**98/07/02**	
44	**9 A.G.**	**T20**	**25.5**	**10**	**559672**	**6070289**	**98/07/02**	**19-24mm**

Anzac River Fry Identification 1998

Vial#	Species	Site	Location	UTM	Northing	Easting	Date Captured	Fork Length (mm)
K	2 A.G.		1 1 KM	10	530079	6072946	98/06/18	14mm, 14mm
L	3 A.G.		3 2km	10	531250	6071827	98/06/18	14mm
M	2 A.G.		7 15km	10	537055	6078923	98/06/18	13mm
N	1 RMWF		8 20km	10	540267	6079791	98/06/18	25mm
O	2 A.G.		8 20km	10	540267	6079791	98/06/18	14mm, 14mm
1	15 Suckers	A5.2		10	534127	6077057	98/07/07	10-15mm
2	1 A.G.	A 5.4	11.6km	10	534807	6077693	98/07/07	26mm
3.1	10 Suckers		14.4km	10	540260	6079951	98/07/08	11-12mm
	3 A.G.							16,22,32mm
3.2	15 Suckers		14.4km	10	540260	6079951	98/07/08	
5	2 Suckers	A1.1	1.4km	10	530208	6072634		12,13mm
6	7 Suckers	A1.1	1.4km	10	530165	6072478		10-14mm
7	5 Suckers	A1.1	1.4km	10	530165	6072478		14-16mm
8	10 Suckers	A1.1	1.4km					11-14mm
9	6 Suckers	A1.2	1.2km	10	530569	6072300		11-14mm
10	4 Suckers	A3.03	2.7km	10	531604	6072090		14mm
11	10 Suckers	A12.0	16.6km	10	538019	6078849	98/07/09	12-14mm
12	1 A.G.	A12.0	16.6km					30mm
13	3 A.G.	A12.1	17.0km					30mm
14	8 Suckers	A12.3	18.2km	10	539052	6079305		11-14mm
16.1	4 A.G.	A13.0	19.5km	10	540345	6079303		20-25mm
16.2	2 A.G.							20-25mm
17	9 Suckers	A13.8	16.5km	10	537802	607858		11-14mm
18	16 Suckers	A9.7	16.2km					11-16mm
19	2 A.G.	A9.6	15.5km	10	537562	6078206		26mm, 26mm
20	28 Suckers		14.6km	10	540813	6080204	98/07/08	12-14mm

Total # A.G.	25

APPENDIX II
Adult Population Estimates

Table and Anzac Rivers Underwater Counts and Mark Recapture Summary Sheet

River (km)	Tagging Date	No. Tagged GR	BT	RB	Vis (m)	No. Obsrs	W Obs	Wet W (m)	Swim Date	Swim No.	Number of fish observed in the swim (4km) and study area (middle 2 km) GR SW	GR st	GR (m) SW	GR (m) St	BT SW	BT St	BT(m) SW	BT(m) st	RB SW	RB St	RB(m) SW	RB(m) St	Fish Observed # Counted GR	BT	RB	Expanded fish Counts GR	BT	RB
Table 9-5	A7&11	7	1	43	6.5	3	39	29	Aug-12	1	2	0	0	0	5	0	0	0	43	23	8	8	2	5	51	2	5	51
		7	1	43	6.5	3			Aug-12	2	3	0	0	0	16	0	0	0	45	14	6	6	3	16	51	3	16	51
Table 22-18	J27	35	1	10	5.5	3	33	21	Jul-29	1	37	6	17	11	13	3	0	0	52	9	2	2	54	13	54	54	13	54
		35	1	10	5.5	3			29-Jul	2	64	14	15	9	21	3	0	0	83	17	1	1	79	21	84	79	21	84
Table 35-31	A5&6	80	19	33	5.5	2	22	12.33	Aug-07	1	86	16	51	45	133	32	6	4	86	39	17	17	137	139	103	135	139	103
		80	19	33	5.5	2			Aug-10	2	94	21	41	36	111	12	4	3	56	17	4	4	135	115	60	134	115	60
Anzac 10-6	A 24	4	0	3		2		32.35	Aug-17	Pre	4	4			0	0			0	0			4	0	0	6.986	0	0
		4	0	3	3.5	4	28	32	25-Aug	1	3	0	0	0	1	0	0	0	1	0	1	1	3	1	2	3	1	2
		4	0	3		4			25-Aug	2	23	23	0	0	4	3	0	0	5	5	1	1	23	4	6	23	4	6
Anzac 16-12	A20				10	2	40	25.52	Aug-13	Pre	1	1			3	0			14	9	0	0	1	3	14	1	3	14
		1	0	11	7	3	42		20-Aug	1	13	0	0	0	8	1	0	0	39	24	4	4	13	8	43	13	8	43
		1	0	11	6	3	36		21-Aug	2	3	0	0	0	11	0	0	0	39	18	1	1	3	11	40	3	11	40
Anzac 34-30	A11-13	65	12	28	12	3	72	27.5	Aug-13	1	80	42	36	29	9	9	9	7	34	23	11	11	116	18	45	116	18	45
		65	12	28	12	3	72		Aug-14	2	88	42	28	25	6	5	2	2	17	17	11	11	96	8	28	96	8	28
six additional tagged gr obs below swim area																												
Anzac 42-39	A18&19				7	2	28	27.33	Aug-14	Pre	142	77			21	9			4	2			142	21	4	142	21	4
	single swimmer after tagging (9gr&1btr					1			Aug-18	Tag		17		30		1		1		1		1						
		48	3	2	5	2	20		Aug-19	1	139	48	28	19	14	5	0	0	3	1	1	1	167	14	4	228	19	5.5
		48	3	2	5	2	20		Aug-19	2	74	24	40	27	12	5	3	3	4	2	0	0	114	15	4	156	20	5.5
		48	3	2	5	3	30		Aug-19	3	81	32	46	26	15	4	6	6	10	4	1	1	127	21	11	127	21	11
Anzac	a 26-27	88	1	4	4.5	2	18	15	27-Aug	1	83	46	74	74	25	15	0	0	3	3	0	0	157	25	3	157	25	3
		88	1	4	4.5	2	18		27-Aug	2	101	56	70	70	20	11	0	0	4	2	2	1	171	20	6	171	20	6

sw swim = 4 km section where the underwater counts were made
st study= the 2 km section where the tags were applied

Table and Anzac River mark-recapture fish population estimates

Arctic grayling

Section River km length m	Surface Area ha	Total Tags M	Total Obs C	Tags Obs R	Est No. N	Std Error	Wgtd Est No.	Std Error of Est No.	Min No. M/N%	Significance Test MC>4N MC	4N	(a) m/r # / ha	(b) u/w # / ha	Cor Factor a/b	m/r # / km	u/w # / km
Table R																
km 9-5	11.6	1	2	0									0.22			0.63
4000	m	1	3	0												
km 22-18	8.4	35	54	17	**105**	20	119	17.4	33%	1890	419	14.20	7.92	1.79	29.82	16.63
4000	m	35	79	15	**171**	37			20%	2765	685					
km 35-31	5.7	80	137	51	**204**	22	219	18.1	39%	10960	817	38.74	24.04	1.61	47.65	29.57
4600	m	80	135	41	**249**	32			32%	10800	997					
Anzac																
km 10-6	17.6	4	3	0									0.74			3.61
3600	m	4	23	0												
km16-12	8.3	1	13	0									0.97			2.46
3250	m	1	3	0												
km 34-30	12.5	65	116	36	**198**	27	203	20.5	33%	7540	794	16.23	8.47	1.92	44.64	23.27
4550	m	65	96	28	**210**	32			31%	6240	840					
km 42-39	10.8	48	167	28	270	45	127	4.9	18%	8016	1080	11.77	12.21	0.96	32.14	33.33
3940	m	48	114	40	**131**	16			37%	5472	523					
		48	113	46	**113**	13			42%	5424	452					
km 47-45	4.0	88	157	74	**178**	15	189	11.6	49%	13816	713	47.17	41.00	1.15	94.33	82.00
2000	m	88	171	70	**205**	19			43%	15048	820					

Bull Trout

Section River km length m	Surface Area ha	Total Tags M	Total Obs C	Tags Obs R	Est No. N	Std Error	Wgtd Est No.	Std Error of Est No.	Min No. M/N%	Significance Test MC>4N MC	4N	(a) m/r # / ha	(b) u/w # / ha	Cor Factor a/b	m/r # / km	u/w # / km
Table R																
km 9-5	11.6	1	5	0									0.91			2.63
4000	m	1	16	0												
km 22-18	8.4	1	16	0									2.20			4.63
4000	m	1	21	0												
km 35-31	5.7	19	133	6	365	126	387	101.0	5%	2527	1459	68.31	21.56	3.17	84.93	26.52
4600	m	19	111	4	427	170			4%	2109	1707					
Anzac																
km 10-6	17.6	0	1	0									0.14			0.69
3600	m	0	4	0												
km16-12	8.3	0	8	0												
3250	m	0	11	0												
km 34-30	12.5	12	18	9	24	5	25	4.7	51%	216	94.2	1.99	1.04	1.91	5.46	2.83
4550	m	12	8	2	37	15			32%	96	149					
km 42-39	10.9	3	14	1	29	16			10%	42	116					
3940	m	3	15	3	15	6	17	4.9	19%	45	61.6	1.58	1.65	0.96	4.39	3.91
		3	21	3	21	9			14%	63	84.7					
km 47-45	4.0	1	25	0		0							5.63			11.25
2000	m	1	20	0												

Rabinbow Trout

Section River km length m	Surface Area ha	Total Tags M	Total Obs C	Tags Obs R	Est No. N	Std Error	Wgtd Est. No.	Std Error of Est No.	Min No. MN%	Significance Test MC>4N MC	4N	(a) m/r # / ha	(b) u/w # / ha	Cor Factor a/b	m/r # / km	u/w # / km
Table R																
km 0-5	11.6	43	51	8	242	70	264	57.5	18%	2193	967	22.73	4.40	5.17	65.91	11.09
4000	m	43	51	6	311	102			14%	2193	1244					
km 22-18	8.4	10	54	2	193	34	223	87.8	5%	540	770	26.51	8.21	3.23	55.68	15.00
4000	m	10	84	1	446	255			2%	840	1785					
km 35-31	5.7	33	103	17	187	39	109	37.8	18%	3399	748	35.74	14.40	2.45	43.34	17.72
4600	m	33	60	4	395	154			8%	1980	1579					
Anzac																
km 10-6	17.6	3	2	1	6	2	6	1.8	52%	6	23.1	0.36	0.23	1.60	1.77	0.87
3600	m	3	6	1	13	7			22%	18	53.9					
km 18-12	8.3	11	43	4	101	39	111	37.2	11%	473	403	13.44	5.01	2.68	34.26	9.02
3250	m	11	40	1	235	132			5%	440	939					
km 34-30	12.5	28	45	11	106	25	76	12.4	26%	1260	423	8.05	2.92	2.08	16.72	7.93
4550	m	28	28	11	67	14			42%	784	267					
km 42-39	10.8	2	4	1	7	3	8	3.0	28%	8	29	0.75	0.65	1.20	2.13	1.52
3940	m	2	10	1	16	8			13%	20	63.8					
		2	4	0												
km 47-45	4.0	4	3	0												
2000	m	4	6	2	11	4			36%	24	44.8					

* tag numbers have been reduced by 5% to account for hooking mortalities and tag loss in estimating the population

M = number of marked fish C=number of fish observed R= the number of marksed fish obse N= estimated number of fish
Wgtd Est No. = weighted estimated mean number of fish
M/N=%of the estimated population that was tagged. For an unbiased estimate the number should be >20% (Vincent 1971)

m/r #/ha mark recapture estimate of the number of fish per hectare u/w #/ha under water counts of the number of fish per hectare Cor Factor Correction factor m/r #/km mark recapture estimate of number of fish per kilometre u/w #/km underwater counts of the number of fish per kilometre.

APPENDIX III Age 0+ And 1+ Habitat Utilisation

Habitat characteristics for beach seine sample sites on the Parsnip River, recorded July 21-24, 1998.

Site No.	Ave. Channel Width (m)	Site Length (m)	Weighted Site Length	Ave. 1m Depth (m)	Ave. 1m Velocity (m/s)	1m Depth x Velocity *	Ave. 5m Depth (m)	Ave. 5m Velocity (m/s)	5m Depth x Velocity *	Ave. 10m Depth (m)	Ave. 10m Velocity (m/s)	10m Depth x Velocity *	Ave. 15m Depth (m)	Ave. 15m Velocity (m/s)
1A	66	25	0.01144	0.10	0.00	0.0000	0.36	0.26	0.9360	0.46	0.45	2.0700	0.58	0.66
1B	31.8	100	0.04577	0.08	0.16	0.1280	0.39	0.71	2.7690	0.75	1.21	9.0750	0.89	1.33
1C	33	50	0.02288	0.16	0.02	0.0320	0.56	0.05	0.2800	0.92	0.29	2.6680	0.99	0.74
1D	62	80	0.03661	0.08	0.09	0.0720	0.40	0.49	1.9600	0.67	0.66	4.4220	0.78	0.68
2A	80.1	150	0.06865	0.07	0.03	0.0210	0.40	0.20	0.8000	0.73	0.32	2.3360	1.09	0.38
2B	90	25	0.01144	0.21	0.00	0.0000	1.02	0.00	0.0000	1.39	0.01	0.1390	1.58	0.12
2C	71.2	105	0.04805	0.11	0.04	0.0440	0.35	0.16	0.5600	0.86	0.37	3.1820	1.40	0.66
3A	122.3	75	0.03432	0.04	0.07	0.0280	0.10	0.10	0.1000	0.21	0.16	0.3360	0.44	0.36
4A	26.7	50	0.02288	0.04	0.02	0.0080	0.39	0.22	0.8580	0.66	0.69	4.5540	0.93	1.28
5A	56.3	160	0.07323	0.17	0.03	0.0510	0.47	0.28	1.3160	0.82	0.55	4.5100	0.99	0.68
5B	64	180	0.08238	0.05	0.01	0.0050	0.22	0.17	0.3740	0.48	0.36	1.7280	0.70	0.52
5C	90.4	100	0.04577	0.05	0.03	0.0150	0.28	0.31	0.8680	0.59	0.55	3.2450	0.78	0.76
6A	45.8	125	0.05721	0.04	0.02	0.0080	0.24	0.27	0.6480	0.55	0.65	3.5750	0.79	0.86
7A	61.8	75	0.03432	0.03	0.00	0.0000	0.14	0.15	0.2100	0.30	0.32	0.9600	0.65	0.46
8A	41.3	50	0.02288	0.08	0.04	0.0320	0.38	0.26	0.9880	0.86	0.49	4.2140	1.26	0.75
8B	53.3	50	0.02288	0.05	0.01	0.0050	0.28	0.01	0.0280	0.47	0.05	0.2350	0.82	0.16
9A	48	140	0.06407	0.10	0.07	0.0700	0.58	0.33	1.9140	0.99	0.52	5.1480	1.27	0.59
9B	54.2	100	0.04577	0.09	0.04	0.0360	0.62	0.21	1.3020	1.12	0.34	3.8080	1.37	0.89
9C	71.8	125	0.05721	0.08	0.02	0.0160	0.33	0.29	0.9570	0.61	0.48	2.9280	0.79	0.63
10A	**75**	**100**	**0.04577**	**0.16**	**0.00**	**0.0000**	**0.38**	**0.10**	**0.3800**	**0.40**	**0.24**	**0.9600**	**0.59**	**0.28**
10B	81.3	195	0.08924	0.17	0.03	0.0510	0.51	0.24	1.2240	1.08	0.41	4.4280	1.36	0.47
11A	94	150	0.06865	0.12	0.04	0.0480	0.53	0.28	1.4840	0.83	0.42	3.4860	0.90	0.51
11B	89.8	75	0.03432	0.10	0.01	0.0100	0.45	0.23	1.0350	0.75	0.41	3.0750	0.78	0.51
		2285	1.04577		0.034			0.231						
					0.78	0.0339		5.32	0.2313					

Habitat characteristics for beach seine sample sites on the Anzac River, recorded July 24, 1998.

Site No.	Ave. Channel Width (m)	Site Length (m)	Weighted Site Length	Ave. 1m Depth (m)	Ave. 1m Velocity (m/s)	1m Depth x Velocity *	Ave. 5m Depth (m)	Ave. 5m Velocity (m/s)	5m Depth x Velocity *	Ave. 10m Depth (m)	Ave. 10m Velocity (m/s)	10m Depth x Velocity *	Ave. 15m Depth (m)	Ave. 15m Velocity (m/s)
1A	34.6	100	0.21053	0.06	0.01	0.0060	0.30	0.18	0.5400	0.56	0.32	1.7920	0.73	0.38
1B	25.8	100	0.21053	0.11	0.13	0.1430	0.45	0.46	2.0700	0.67	0.53	3.5510	0.82	0.65
2A	27.8	200	0.42105	0.14	0.09	0.1260	0.31	0.43	1.3330	0.63	0.89	5.6070	0.73	0.81
3A	42	75	0.15789	0.06	0.03	0.0180	0.39	0.13	0.5070	0.68	0.33	2.2440	0.71	0.37

* Value equals Depth (m) x Velocity (m/s) x 10

Site 10A was not used in the habitat preference calculations. It was located at the mouth of the Anzac River and any fry washed down the Anzac river would tend to congregate here.

Substrate characteristics and Number of grayling caught for beach seine sample sites on the Parsnip River, recorded July 21-24, 1998.

Site No.	Site Length (m)	Weighted Site Length	Cobbles (%)	Gravels (%)	Fines (%)	No. 0+Gr	Frequency Value	No. 1+Gr	Frequency Value
1A	25	0.01144	10	85	5	1	0.01190	2	0.04167
1B	100	0.04577	10	85	5	5	0.05952	2	0.04167
1C	50	0.02288	0	90	10	0	0.00000	0	0.00000
1D	80	0.03661	0	80	20	0	0.00000	0	0.00000
2A	150	0.06865	30	20	50	6	0.07143	2	0.04167
2B	25	0.01144	50	0	50	0	0.00000	0	0.00000
2C	105	0.04805	90	5	5	0	0.00000	0	0.00000
3A	75	0.03432	0	70	30	5	0.05952	0	0.00000
4A	50	0.02288	5	70	25	2	0.02381	0	0.00000
5A	160	0.07323	5	85	10	17	0.20238	7	0.14583
5B	180	0.08238	0	90	10	15	0.17857	4	0.08333
5C	100	0.04577	0	75	25	17	0.20238	11	0.22917
6A	125	0.05721	0	60	40	6	0.07143	0	0.00000
7A	75	0.03432	0	85	15	4	0.04762	2	0.04167
8A	50	0.02288	70	25	5	1	0.01190	1	0.02083
8B	50	0.02288	50	25	25	1	0.01190	5	0.10417
9A	140	0.06407	75	15	10	0	0.00000	0	0.00000
9B	100	0.04577	75	15	10	0	0.00000	1	0.02083
9C	125	0.05721	75	15	10	2	0.02381	2	0.04167
10A	**100**	**0.04577**	15	**50**	**35**	**33**	0.39286	**6**	0.12500
10B	195	0.08924	70	20	10	1	0.01190	3	0.06250
11A	150	0.06865	80	15	5	1	0.01190	1	0.02083
11B	75	0.03432	60	30	10	0	0.00000	5	0.10417
						84	1.39286	48	1.12500

Substrate characteristics and Number of grayling caught for beach seine sample sites on the Anzac River, recorded July 24, 1998.

Site No.	Site Length (m)	Weighted Site Length	Cobbles (%)	Gravels (%)	Fines (%)	No. 0+Gr	Frequency Value	No. 1+Gr	Frequency Value
1A	100	0.21053	60	30	10	4	0.22222	0	0.00000
1B	100	0.21053	5	90	5	3	0.16667	0	0.00000
2A	200	0.42105	50	40	10	1	0.05556	0	0.00000
3A	75	0.15789	35	60	5	10	0.55556	1	1.00000
						18.00			

Appendix IV

Arctic Grayling *(Thymallus arcticus)* Fry Identification

Mike Stamford, UBC
10 May, 1999

During June and July of 1998, samples of larval fish were collected from the Table River and the Anzac River for potential use as Arctic grayling DNA samples. These samples were identified as Arctic grayling in the field by roughly scanning their size and gross morphology by eye (Brian Blackman pers. com.). Given their small size and early stages of development, it would have been nearly impossible to identify characters that are unique to Arctic grayling larvae. Identification would have been easier if field personal had the use of a taxonomic key that could focus their attention on specific features. The purpose of this study was to identify morphological features of larval Arctic grayling that can be used for identification in the field. Morphological and molecular genetic analyses were used as two independent (double blind) techniques to identify Arctic grayling larvae from the batch of samples. The identity of the other species (morphologically) was not confirmed with molecular genetic evidence.

Arctic grayling versus Mountain Whitefish *(Prosopium williamsoni)*

Arctic grayling *(Thymallus arcticus')* and whitefish *(Prosopium spp., Coregonus spp,* and *Stenodus* spp.) are closely related (Stearly 1993) so they have similar morphologies. Further, the mountain whitefish *(Prosopium williamsoni)* occurs in similar habitats with Arctic grayling in streams, especially at earlier life history stages (pers. obs.). Consequently these two similar looking species tend to be sampled together and their identity is often confused (Gordon Haas, pers. com.). There are 3 obvious morphological features that can be used to distinguish Arctic grayling from other species of fish (Scott and Crossman 1973). The presence of an adipose fin distinguishes northern fish fauna as salmonids (Salmonidae) or trout perch (Percopsidae). From this taxonomic level, grayling and whitefish can be readily distinguished because they have significantly larger scales and their caudal fin is relatively forked. Finally, fully developed Arctic grayling can be distinguished from whitefish because their dorsal fin has more than 17 principle rays and the base is longer than the length of the head. Whitefish (and all other salmonids) have fewer than 17 dorsal fin rays and the fin base is shorter than the length of the head (Figure 1).

In samples collected early in the spring, mountain whitefish larvae (0+) are expected to be larger and further developed than Arctic grayling fry. This is because mountain whitefish spawn in the fall (Arctic grayling spawn in the spring) and most likely emerge from the gravel earlier than Arctic grayling (Scott and Crossman 1973). Underdeveloped Arctic grayling larvae are likely to be found at the same time as fully developed (all their fins have formed) mountain whitefish larvae but not with underdeveloped mountain whitefish larvae. Morphological examination of the samples collected from the Table and the Anzac showed the above expectation (Figure 1). All of the mountain whitefish in the samples had fully developed fins while the Arctic grayling were smaller and many of

them had not yet developed their dorsal or anal fins. Genetic analysis revealed that only some of the underdeveloped larvae were Arctic grayling. Further examination under the microscope was done to find morphological structures that distinguish between the remaining underdeveloped larvae in the sample.

Arctic Grayling versus Longnose Suckers *(Catasotmus catastomus)*

Distinguishing between species of fishes that are at an early larval stage of development is especially difficult. This is partly because of their small size, but also because related taxa tend to follow similar ontogenic pathways (ie. they look more similar at earlier stages of development; Moser et. al. 1984). Different species of early larvae tend to be sampled together when these different species spawn in similar habitats at similar times of the year. Arctic grayling and longnose suckers *(Catasotmus catastomus)* start their spawning migration into streams at similar water temperatures in early spring (Scott and Crossman 1973, McPhail and Lindsey 1970). It is not surprising, therefore, those larvae of these two species were found foraging in the same areas when these samples were collected. Further, the larvae of these two species were found to be remarkably similar in the length between the tip of the head and the anus, relative to the total length. This feature has been used to identify longnose sucker larvae from other species (Don McPhail pers, com.).

The most obvious morphological differences between the larvae of the two species were determined through examination under the microscope. It was first noticed that Arctic grayling were larger than longnose suckers (Figure 2). Arctic grayling larvae that were nearly the same size as the sucker larvae had yellow-orange yolk sacks located in the gut cavity while all of the sucker larvae had fully absorbed yolk sacks. Arctic grayling larvae had apparent premaxillary bones while the longnose sucker larvae had terminal mouths with small more delicate bony structures around the mouth (Figure 3). Finally, the melanophores of the longnose suckers extended equally along the whole length of the body both dorsally and ventrally. Arctic grayling larvae have melanophores running the length of the body dorsally in a similar pattern to the suckers, but ventrally pigmentation is constrained to the anterior region around the belly (Figure2).

Conclusion

Morphological differences between the larvae of mountain whitefish and Arctic grayling were most significant in these samples because underdeveloped whitefish were not found with underdeveloped grayling. Even the least developed whitefish that were sampled could be distinguished from grayling by the morphology of their dorsal fin. The growth rate of Arctic grayling fry relative to whitefish fry should be investigated further because both species appear to exploit similar habitats throughout their life history. How they partition the resources might have something to do with their size at age. If Arctic grayling hatch later but grow faster than mountain whitefish fry then there must be some period in the summer when they are very similar in size and competition for resources reaches a peak.

The most useful distinguishing features of the larvae of longnose suckers and Arctic grayling were the difference in size and the different pattern of pigmentation along the belly. The different structures on the mouth might prove difficult to assess in the field without the use of a hand lens, owing to the size of the larvae. Further investigation into the spawning and rearing habitats exploited by Arctic grayling and longnose suckers is needed to reveal how interactions between these species affects their abundance. Alteration of habitat may swing the balance so conditions become more beneficial for one species relative to the other.

References

McPhail, J.D. and C.C. Lindsey. 1970. Freshwater fishes of nothwestern Canada and Alaska. Fish. Res. Bd. Can. Bull. 173.

Moser, H.G., D.M. Cohen, M.P. Fahay, A.W. Kendall Jr., W.J. Richards and S. L. Richardson (eds). 1984. Ontogeny and systematics of fishes. Special Publication no. 1. Arner. Ichthyol. Herpetol., Lawerence, KS, USA.

Stearley, R.F, and Smith, G.R. 1993. Phylogeny of the Pacific trouts and salmons *(Oncorhynchus)* and geners of the family Salmonidae. Trans. Arner. Fish. Soc. 122: 1 - 33.

Scott, W. B. and E.J. Crossman. 1973. Freshwater fishes of Canada. Fish. Res. Bd. Can. Bull. 184.

Figure 1. Photograph of 1 mountain whitefish larva (top) and 2 Arctic grayling larvae (bottom) at different stages of development. Note the longer dorsal fin base on the developed grayling larva and the relative size of the smaller grayling with the whitefish. The whitefish larva was sampled on 11 June 1998 and the small and large grayling were sampled on 16 June and 30 June, respectively, The least developed whitefish larva found in the whole sample was chosen for this picture. The top 22 mm long line refers to the top 2 fish and the 25 mm long line refers to the bottom Arctic grayling that came from a picture that was taken with a lower magnification,

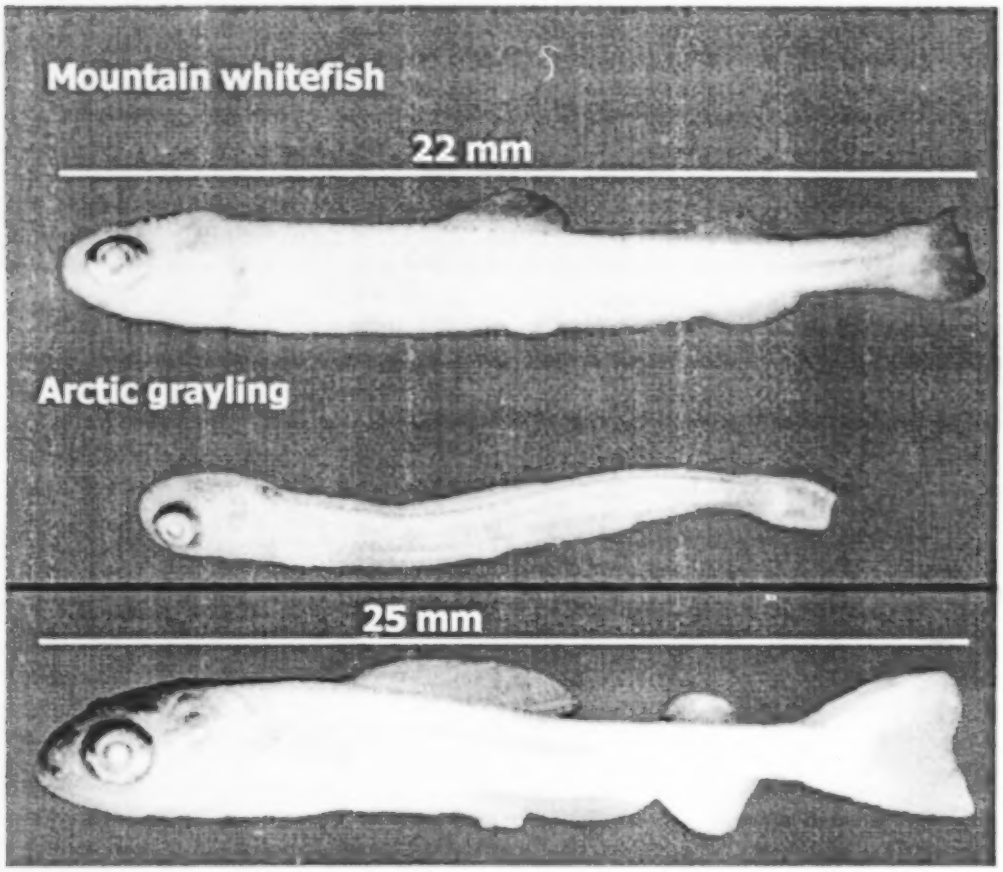

Figure 2. Photograph of Arctic grayling and longnose sucker larvae, Note the difference in size between the two species with reference to the 11 mm line. Also note the pigmentation along the ventral length of the body is located on the belly in Arctic grayling while pigmentation runs the length of the body, ventrally in the longnose suckers. The grayling were collected on June 17 and the suckers were collected on June 30, 1998.

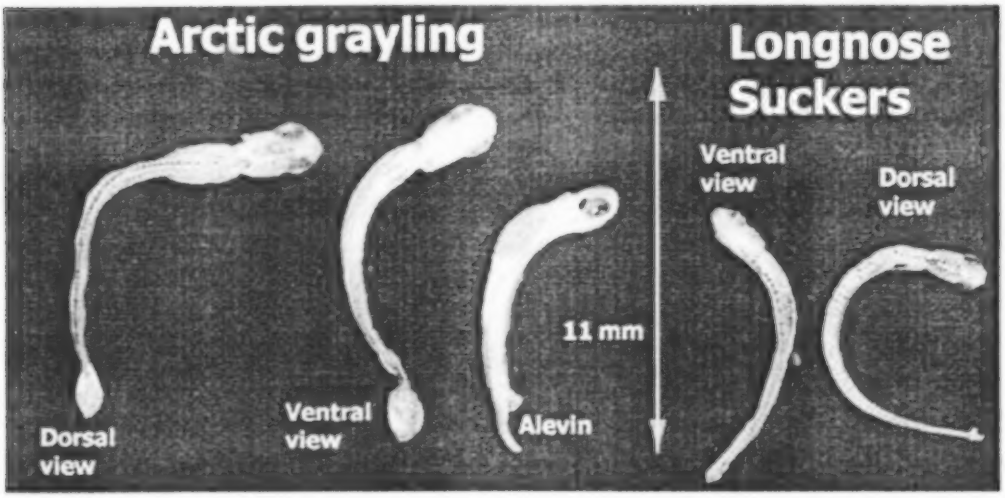

Figure 3, Magnified photograph of samples from figure 2 showing the differences in mouth morphology between Arctic grayling and longnose sucker larvae. Note the larger premaxillary bones on the mouth theat is more ventrally located in the Arctic grayling larvae.